Popular Astronomy

Vol. LIII, No. 10 DECEMBER, 1945 Whole No. 530

Observations of the Total Solar Eclipse by the "Princeton Party" and Volunteers

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PART I

This report summarizes observations on July 9, 1945, made by the "Princeton Party" near Malta, Montana, and by 46 collaborating volunteer groups who were stationed from Oregon to Saskatchewan. The observations of a total of 220 persons are represented, including the unsuccessful attempts of a few who met with the misfortune of completely bad weather.

The principal results come under the following headings.—Successful photographs of the corona in color were made by the Freemans. Two motion picture films show the inner corona during the whole of totality, and the retreat at 2½ miles a second of the moon's shadow near third contact across broken clouds. The retreating shadow was shown also on a still color-photograph made by the Montana State University party at Saco.

Photometric measurements by Stokley and Benford gave the illumination on a vertical surface during totality as of the order of a foot candle, satisfactorily confirming a previous computation by Stewart and MacCracken of what scattering of light by clear air outside the shadow produces. In consequence of this confirmation of the theory it is now possible to state approximately what will be the illumination at an eclipse, as a function of size of shadow, altitude of sun, and cloud cover. Direct light from the corona is insignificant in comparison with the scattered sunlight. In passing, the warning is worth giving that the Fraunhofer spectrum included in spectrograms of the corona must be produced at least in part, by sunlight outside the shadow scattered by our air into the line of sight and then rescattered.

Predicted phenomena relating to the "falling shadow" at a total eclipse near sunrise were thoroughly confirmed by visual inspection at many stations. The moving shadow in the air was plainly seen at points at least 45 miles outside the path of totality. There is strong evidence that the shadow was seen and photographed before sunrise at Portland, Oregon, as it came down through the air to tangency with the ground 320 miles away at Cascade, Idaho. From a mountain top two lookout men of the U. S. Forest Service report a new phenomenon apparently related to shadow bands. The procedure followed to secure a number of volunteer observers at this eclipse proved highly successful. A

mimeographed questionnaire calling for certain observations was broadly distributed in advance, especially through the good offices of the Forest Service.

Observations Near Malta

The "Princeton party" is so named merely for convenience. In addition to 60 volunteers, most of whom were from Malta and vicinity, it included Dr. and Mrs. Ira M. Freeman, Apprentice Seaman William L. Hopkins, Jr.; and Messrs. James Stokley, of the General Electric Company, Schenectady, and John Q. Stewart. All except A/S Hopkins arrived the morning of July 5. Mr. Frank Benford, also of the General Electric Company, although unable to be present, provided a special camera and later took charge of calibrating the photometric readings. As assistance of various sorts was required with cameras, photometers, and visual observations, the enrollment of volunteers was begun at once. By way of rehearsals, three meetings were held in the City Hall.

Because of large reliance upon supplementary observations by local assistants, our relations with the people of the vicinity and our indebtedness to them were more important than is usually the case at eclipse stations. We are sorry that space does not permit publishing every individual name. Mr. Emanuel Sklower was our general guide and benefactor; Mayor H. G. Mebust made us welcome; Mrs. Gladys Costello was invaluable in enrolling assistants and in many other ways; Mr. Dale Waters and State Senator Fred Robinson led us to the best eclipse site. Mr. Frank Hromas, local manager for the Montana Power Company, granted use of his shop; Mr. and Mrs. Homer Sherlock took good care of us at their hotel; Messrs. Russell Leach, Harry Lyden, and Sergeant James Parker lent or operated cameras; Mr. Ray Veseth helped in several ways, and his uncle, Mr. Carl Veseth, put a cub plane at our disposal. Mrs. Edward Donlan and Captain J. R. Larcombe gave us excellent preliminary introductions; Mr. and Mrs. N. J. Boothe extended special hospitality at their ranch.

Into our loosely but effectively organized party we were glad to welcome several individuals who had made long journeys to see the eclipse, including Messrs. Artig and Morgan, of Minneapolis, and Lindsay, of San Francisco. Each of these has published a report of his own activities.[1] Additional notes have been published.[2]

The observations at Malta were in five departments: photographs of the sun during totality, photometric measures of the general illumination,

[1] J. L. Artig, *Popular Astronomy*, **53**, 321, 1945; W. D. Morgan, *Popular Astronomy*, **53**, 321, 1945; Lewis Lindsay, *Sky and Telescope*, September, 1945; *The Argonaut*, September 28, 1945.

[2] I. M. Freeman, *Science Illustrated*, September, 1945. J. Q. Stewart and James Stokley, *Sky and Telescope*, September and October, 1945. Mention may also be made of Stokley's two articles in *The New York Times*, July 9, and 10, 1945, as well as the article in *Time* Magazine, July 23, 1945, based on an account by Gladys Costello.

visual inspection of the moon's shadow in the air as it approached and receded, visual inspection of the corona, and identification of planets and stars visible during totality. To each department volunteer assistants were assigned.

In addition Stokley made a series of photographs of the whole hemisphere of the sky with a camera especially designed by Benford. It was hoped that these would catch the moon's shadow in the air, but, because of an altocumulus overcast, all were underexposed. And Mr. Artig flew as passenger in Mr. Veseth's airplane—Harold Ebaugh being the pilot —and observed totality from a point about 30 miles northeasterly.

The site we selected was on a flat-topped hill in the open prairie, about 15 miles SSW of Malta, just east of Scandia Lutheran Church, at about N 48° 12′, W 107° 47′—a mile or two northwest of the central line. The shadow belt here was 33 miles wide. The shadow on the ground was an ellipse 22 miles in minor axis and 180 miles in major axis.[3] The sun's altitude during totality was 7° and the predicted duration 30 seconds. The elevation of 2500 feet afforded a splendid view over 40 miles to the Little Rocky Mountains, in the direction from which the moon's shadow approached. The five groups of observers were stationed close enough together for the count of seconds to be heard by all. Besides the 65 people in the party, there were onlookers to the number of perhaps 150—notwithstanding the early hour, the sparsely settled country, and the rationing of gasoline. One resident said, "Those ranchers and cowpunchers came to see the crowd, but they stayed and got all hopped up about the eclipse!"

Two excellent Longines watches kindly lent for the occasion were checked daily at the Western Union Telegraph Office by the 0955 MWT signals. The predicted instant of second contact was $6^h\,15^m.0$. At 4 minutes before this instant by the watches, a preliminary call of time remaining was begun by A/S Hopkins. The "Go" signal for observed second contact was given by Stewart, and according to it the preliminary count had been 3 seconds slow—an expected tolerance. Because of the very slight excess of the moon's angular diameter over the sun's, the crescent of photosphere did not begin to shorten rapidly until it was very thin, only 10 seconds or so before second contact. A call of 7, 14, 21, and 28 seconds during totality, with a final call at 35 seconds, was made by the Rev. Mr. Eugene Schneider, who also clocked the interval to the diamond ring at third contact as 30 seconds, just the predicted duration.

A general altocumulus overcast which was moving southward very slowly interfered seriously with all observations except direct inspection and photography of the corona itself. As second contact approached, the sun climbed up into one of those miraculous little "windows" which occasionally serve eclipse observers, and shone in deep blue sky from

[3] J. Q. Stewart, *Sky and Telescope*, May, 1945.

0608 until totality began. There was no cirrus or other higher cloud, but the photographs show broken clouds close to the sun during totality, and the sun disappeared into the upper altocumulus cloudbank at 0619.

The diamond ring at second contact was conspicuous, and again at third contact. No one in our party saw "Baily beads" or prominences or shadow bands. The coronal streamers appeared an instant or two before the last speck of solar crescent vanished at second contact. A number of seconds before second contact the forward edge in the air of the moon's shadow already had passed our zenith, moving toward the sun. It crossed the sun, and totality began, but still ahead of the shadow, below the corona in the northeast, sunlit air threw for a few more seconds the same saffron glow as was reported June 8, 1937, from the *Steelmaker* in the Pacific.[4] Close above this tawny twilight glow the slate-blue shadow revealed the chromium coronal streamers. This contrast of colors so closely juxtaposed occurs only at low altitudes, and not at zenith eclipses. The narrowness of the rift in the clouds through which these phenomena were visible added to their picturesqueness.

Photographs. The Freemans had begged, borrowed, and brought as many fast cameras and as much color film as they could. Dr. Freeman, who has been busy with war work, hopes to describe the photographic results more adequately in a later paper. Between the two diamond rings they and their assistants secured 12 still photographs in color, with exposures at f. 4.5 ranging from 1/25 second to 6 seconds, and including also exposures with smaller apertures. The shortest ones show, of course, only the inner corona. Longer ones show the base of the coronal shaft. The 6-second exposure is a beautiful view in which the outer corona can be traced to the lower left, and perhaps also the upper right, as far as 3 diameters each way—a total extent of 7 diameters including the eclipsed disk of the sun itself. At about 4 diameters to the upper right, Saturn shines through the broken clouds into which the sun was climbing as the eclipse ended. This is the only photograph of the corona with which the writers are familiar which compares in beauty with the late Mr. Howard Russell Butler's paintings. Copies are not yet available.

Each of the two 16 mm motion picture color films shows the inner corona from diamond ring to diamond ring, with indications of the moon's motion across the sun. The most interesting thing on these films is what may be the first direct record in pictures of the motion of the moon's shadow. The field of view is about 10° with the sun in the center. A second or so before third contact the lower edge of the upper cloud bank shines out in golden light. The returning sunlight can be seen flitting down the broken clouds to the sun itself, and when it reaches it, the diamond of photosphere begins to appear. Below this

[4] J. Q. Stewart and James Stokley, *Publ. A.S.P.*, **49**, 186, 1937; *Pop. Astr.*, **45**, 358, 1937; J. Q. Stewart and C. W. MacCracken, *Ap. J.*, **91**, 51, 1940.

the light is lost as it crosses the entirely clear rift of sky, until suddenly the upper margin of the lower cloud bank turns golden. The overcast was reported by the airplane observers to be at about 11,000 feet, so all the trigonometric details are available to directly measure the speed of the retreating shadow—something like 150 miles a minute.

It is evident that the traditional long-focus (but slow) lenses are not the only useful means of eclipse photography. In this connection the writers take the liberty of recording a recent statement made in conversation by an astronomical friend, to the effect that most existing lenses do not possess flatness of field adequate to obtain anything like their theoretical resolving power for objects not on the exact axis. The eclipse of May 20, 1947, in South America and the South Atlantic, ought to provide photographs of the corona superior to any yet obtained.

Dr. Freeman's estimates of what exposures would be desirable were largely based on a mimeographed memorandum prepared by the Eastman Kodak Company, and turned out to be very successful. He is indebted to the Bausch and Lomb Co. and to the Wollensak Optical Co. for the loan of equipment, as well as to the Eastman Co. for careful development of the color films, and to Messrs. L. L. Snyder, H. Strauss, and W. vB. Roberts for the loan of cameras.

The Photometric Study. So far as we know, measurements of the general illumination from moment to moment on surfaces exposed in various directions have not hitherto been obtained during totality. A theoretical study suggested by visual inspection at the long eclipse of June 8, 1937,[5] established that scattering of sunlight by pure air outside the limits of the umbra would account for all the effects there observed. It was computed, furthermore, that the resultant illumination on a vertical surface at mid-totality at the noon point at that eclipse was 0.6 foot-candle. This computation was stated as being somewhat less than the actual value, as "secondary scattering" was not allowed for.

For comparison, the corona, if half as bright as the full moon, would give an illumination of about 0.012 foot-candle on a surface lying at right angles to its direction. The zenith sun illuminates a horizontal surface at sea-level with 9000 foot-candles on a clear day, according to the old measurement by H. H. Kimball.

In preparing for the eclipse of last July 9, Stokley and Stewart considered building an automatically-recording bank of photometers for obtaining readings of scattered skylight in various directions from moment to moment as the moon's shadow raced overhead. A General Electric string-galvanometer was available with which a reading could be recorded on a moving tape every second or so. A motor-driven selector switch could have been constructed to program the photometer circuits one at a time to this recorder. But wartime conditions forbade

[5] J. Q. Stewart and C. D. MacCracken, *loc. cit.*

assembling these devices, with the required 120 volt storage battery or generator, on a light truck or station-wagon. At the selected base of Malta, commercial power lines are confined to a narrow strip along the Milk River. In view of these factors it was decided to rely on volunteers for reading and recording the currents produced by barrier type photocells, which require no outside source of voltage. This decision proved successful, but only because of the enthusiastic, alert, and unselfish cooperation of the volunteers enlisted at the enterprising ranch town.

A rectangular wooden box a couple of feet on a side was placed on the ground, with the two ends lying exactly in the azimuth of the totally eclipsed sun (26° N of E, 26° S of W), and the two sides at right angles (26° E of S, 26° W of N).

General Electric photocells were placed on each end, each side, and on the top. From each of these five banks two wires about 25 feet long led to five milliammeters, also supplied from the G. E. Research Laboratory. At each extremity of this "pentapus" were stationed two volunteers, one to read his or her milliammeter at the call of arranged times, the other to hold a flashlight and to record the reading. It was found in rehearsals that if readings were made at 7 second intervals no one was hurried or flustered and each observer would have the opportunity of intermediate glimpses of the corona. This "fully automatic Maltese photometer" worked very well. The milliammeter readings were later calibrated by Mr. Frank Benford at the General Electric Research Laboratory, with the results given in Table 1 for readings taken during totality.

TABLE 1

PHOTOMETER READINGS, FOOT-CANDLES

	Go	7 sec.	14	21	Averages
SW	0.59	0.59	0.59	0.59	0.59
NE	0.30	0.27	0.36	0.39	0.33
SE	0.16	0.16	0.21	0.27	0.20
NW	0.55	0.50	0.45	0.45	0.49
Average of above	0.40	0.38	0.40	0.42	0.40
Zenith	0.19	0.17	0.17	0.19	0.18

NOTE: Exact azimuths are given in the text. Individual readings are not expected to be accurate to 0.01.

The reaction times of the observers were not determined, but each reading must correspond to a moment a couple of seconds later than the indicated second. The indices of the milliammeters did not move very much, and it required close attention in the dim light to get a reading. The existence of appreciable reaction time is shown by the fact that the five readings at 28 seconds averaged much larger than those at "Go," being, in the same order as in the table, 1.17, 0.64, 0.43, 0.50, 0.24. The five readings at 35 seconds (third contact having been just at 30 seconds) were 1.76, 1.18, 0.64, 0.65, 0.48.

The existence of the altocumulus overcast reduces the general validity of the readings of Table 1. Equality from instant to instant between the "SE" and "NW" readings, athwart the shadow, would undoubtedly have been obtained in clear weather; while the "SW" and "NE" readings would have been equal on opposite sides of mid-totality. It is interesting that successive averages of these five readings are constant at 0.4 foot-candle. It may be assumed, as a rough correction, that this value was reduced by a factor of 2, by the overcast. Altocumulus is not a heavily opaque cloud.

In places where this eclipse was observed with clear skies the general illumination does not appear to have been very different from that at the position of the *Steelmaker* on June 8, 1937. There the moon's shadow was a circle 155 miles in diameter—instead of an ellipse 22 x 180 miles. But the sun was near the zenith instead of near the horizon, and this cause of increased illumination would have tended to compensate for the larger shadow. Where skies were clear in 1945, ordinary newspaper print and the second-hand of a watch could be read, and no stars or planets fainter than first magnitude could be seen. Just about the same degree of general illumination occurred near the noon-point in 1937. Accordingly we can assume that something like 0.8 foot-candle on a vertical surface at mid-totality represented the actual illumination at the *Steelmaker* in 1937, and that the illumination at Malta in 1945 would have been the same without clouds.

Near the sunset point in 1937—from Moro, Peru, at 2400 feet—third magnitude stars were reported as identified by Bailey and Korff through the clear air; the sun's altitude during totality was 8° as compared with 7° at Malta. Stewart and MacCracken concluded that the factor of reduction in general brightness probably was more like one magnitude than two from the noon-point to Peru.

We may state that Malta in 1945 probably would have had in clear weather, with the smaller shadow, about as much light as the noon-point had in 1937—the lower altitude of the sun at Malta compensating for the increased scattering into the smaller shadow there. Applying again a factor of one magnitude from a low sun to a zenith one, it appears that a zenith sun with a circular shadow only 20 miles in diameter would give an eclipse something like a magnitude brighter than *Steelmaker* or Malta. (As Venus can with difficulty be seen in full sunlight with clear air, the total range of illumination produced by scattering, from full uneclipsed sunlight to the darkest clear-weather eclipse with a low sun is about 7 magnitudes. This range is confirmed by Kimball's measurement of 1000 foot-candles as the illumination on a horizontal surface produced by scattered light from the sky with a zenith sun.)

Table 2 combines these conclusions into approximate predictions for a wide range of eclipse conditions.

TABLE 2

ROUGH PREDICTIONS OF GENERAL ILLUMINATION AT MID-TOTALITY: SEA LEVEL

Diameter of shadow cone	Altitude of sun	Check point	Foot-candles on vertical surface at mid-totality (averaged for all azimuths)	Magnitude limit of stars identified by average observer
miles				
180	8°	Moro, 1937	0.3	2
180	90°	*Steelmaker*, 1937	0.8	1
20	7°	Malta, 1945	0.8	1
20	90°	None	2.0	0

NOTE: The above estimates assume clear sky, and the value at Malta has been increased from the 0.4 foot-candle actually observed there with clouds. Cloudiness reduces the illumination, but it requires heavy clouds to bring about a reduction of more than a magnitude. The first effect of clouds is to diffuse and distort the illumination. Haze as well as actual cloudiness may exercise an effect. With a large shadow haze will reduce the brightness. Scattering is less as observed from a flat-topped hill at a high elevation than at sea level, because of the diminished mass of atmosphere. A horizontal surface at mid-totality will receive half or less than half the illumination of the average vertical surface—the difference being more marked the larger the shadow. An absolute error by a factor of 1.5 in the estimates of foot-candles and magnitude limits would not be surprising.

Before leaving the subject of the photometric observations it is worthwhile to record that the following illuminations in foot-candles were obtained from a bank of photocells exposed to only 450 square degrees of sky at the zenith, before second contact: —90 seconds, 0.42; —75, 0.33; —60, 0.25; —45, 0.17; —30, 0.08; —15, 0.00. The exposure was to about 2 per cent of the hemisphere. The light fell off about linearly at the rate of 0.005 foot-candle per second, until the advancing edge of the shadow passed overhead a number of seconds before second contact. The shadow existed in the air in depth and not as a sharp-edged projection on a thin surface. Apparently two fliers in central Montana had the luck to see the shadow very clearly projected on a thin cirrostratus overcast, but details are not available.

Remaining Observations. The visual observations of the moon's shadow, of stars, and the corona can be rapidly disposed of. The overcast interfered so much with the first-mentioned that it is better to save the space for the more fortunate observers at other stations. Here and there on the cloud layer the shadow-margin could be seen momentarily rather sharply projected. The saffron glow athwart the shadow at mid-totality extended only about 3° above the horizon, being cut off by the cloud—as compared with 14° with the larger shadow at the *Steelmaker*.

Venus was the only planet or star seen at Malta. It was visible of course even before and after totality. Saturn shows on the longest-exposed photograph, as already stated. It may have been hidden behind a small fleck of cloud during part of totality, and so missed on that account by the visual observers. Its magnitude was 0.3.

Fifteen observers who never before had seen the corona had been

instructed to concentrate on one problem only: Does the "globular corona" exist? The consensus was that it does—that the streamers are more like searchlight beams thrown through an already luminous fog than like shafts of light projected against a dark background. The clarity of the air of Montana more than compensated for the low altitude of the sun in affording good definition, and this corona was seen as extending farther and as showing more delicate detail than those Stewart saw from Long Island January 24, 1925, and from Locke Mills, Maine, August 31, 1932. The long equatorial streamers of the expected sun-spot minimum type extended farther than near maximum June 8, 1937.

In relation to the vapor trail noticed by Artig and Ebaugh as having formed in the track of totality,[6] Dr. G. A. Campbell reports to the writers that at the eclipse of August 31, 1932, a light mist formed temporarily at the ground during totality, at an elevation of 1800 feet or so in the White Mountains.

Of the 65 observers in our party only two, Stokley and Stewart (who each had seen three), had ever seen a total eclipse before. Naturally some of the visual observations were handicapped in consequence of this inexperience.

Malta was selected as an easily accessible base after a few hours' library study revealed that: (1) The increase in spectacularness of the "falling shadow" at points southwestward in Montana and Idaho was offset by the unfavorability for coronal observations of the sun's lower altitude there, and by the much greater difficulty of selecting an easily accessible eclipse site in the rugged country west of the Little Rocky Mountains. (2) To the northeastward, on the other hand, average weather prospects continued to become gradually less favorable, and the shadow projection became less elongated and less interesting.

In addition to acknowledgments already made, we have to express our indebtedness also to the U. S. Navy, and to Captain Frederick G. Richards, U.S.N., the Commanding Officer at Princeton, since A/S Hopkins travelled to Malta under orders to assist in the observations, and to the Princeton University Observatory. Also to the Corps of Engineers, U. S. Army, for a map of the Malta Quadrangle, to the General Electric Co., and the Longines Watch Co.

[6] J. L. Artig, *loc. cit.*

(Part II to follow in next issue.)

Christmas and the Stars

By KAREL HUJER

At least once a year men, absorbed in their daily affairs, pause and fleetingly ponder over the story of the silent night of nativity, a mysterious night whose stars appear to be more glorious, more prophetic, more significant than those of any other night. What is the origin of this ancient and mysterious holiday? What is the meaning of the Christmas tree which brightens our thoughts by the fireside? What is the Advent Star or Bethlehem Star which persistently returns as our closest association with the Yuletide?

Perhaps few of us realize that these questions concern some of the most fundamental phases of the history of human civilization. Their interpretation sheds light upon the earliest stages of man's awakening culture, thousands of years before the invention of script. The records of those ages were not expressed in writing. Rather, events, knowledge, hopes, views, and religions were perpetuated and communicated verbally in the strange form of phantastic, childlike imaginative stories. It was the infancy of humanity, it was the age of mythology wherein veiled truths were preserved.

Mythology is not meaningless legend. It is only another form of recording. It is a language in itself and if we wish to study man's mind, his civilization of some ten thousand or more years ago, we must resort to mythological stories, the only relics preserved by tradition. Just as from the present appearance of the cosmic universe we can read its history, so through mythology we are enabled to read the ancient history of mankind. A mythological story very clearly associates Christmas rites with the winter solstice. This is the nucleus of all yuletide symbolism.

Symbolic Appropriateness

Christmas as the winter solstice celebration was observed by the Romans who inherited this custom, in an integrated form, from preceding ancient civilizations of the Mediterranean area. Edward Tyler, F.R.S., in the second volume of his Primitive Culture writes: "The Roman winter solstice festival, as celebrated on December 25 in connection with the worship of the Sun-god Mithra, appears to have been instituted in this special form by Emperor Aurelian about A.D. 273, and to this festival the day owes its apposite name of Birthday of the Unconquered Sun, *Dies Natalis Solis invicti*. With full symbolic appropriateness, though not with historical justification, the day was adopted in the Western Church, where it appears to have been generally introduced by the fourth century, and whence in time it passed to the Eastern Church, as the solemn anniversary of the birth of Christ, the Christian Dies Natalis, Christmas Day."

There is no question but that the already very ancient and deeply rooted religion of the Sun offered strenuous resistance to the invasion of Christianity. Although externally it caused considerable religious change in the civilized world when Constantine, that ardent votary of the Sun, abandoned the faith of Apollo for that of Christ, internally the change was not of any great import. For the most part, the ancient rites of solar worship are paralleled in modern Christendom in several ways, two being most outstanding: by the ceremonies connected with turning toward the East and secondly, in the continuance of the great sun festivals countenanced by or incorporated in Christianity. Easter, being another festival originally connected with both solar and lunar rites, is perhaps more ancient than Christmas itself.

The Yule Log

If the correlation of Christmas with the winter solstice is an established fact, let us proceed to interpret the present rites and customs. In many places in Europe, Christmas is celebrated by bonfires and the burning of a yule log. Linguistically, the word yule or its ancient form "Hiaul" or "Huul" signifies the Sun in some languages. The English word "wheel" is etymologically derived from yule, the old name for the Sun, and the wheel is one of the most ancient symbols of the Sun, the spokes representing the Sun's rays. Yuletide may be directly translated as Suntide. Christmas as the winter solstice really means a great turning point in the apparent celestial movement of the Sun; the Sun has reached the lowest position in the sky, astronomically speaking, a declination of 23.5 degrees below the celestial equator. Practically speaking, this means the shortest days and longest nights of the year in the northern hemisphere. Ages ago, the night must have seemed long and dreary to primitive man in his unlighted cave. It must have been a distressing experience filled with eerie scares and visions so vivid to his primitive mind. When he discovered, many thousands of years ago, that the sun does not go down in the sky to disappear forever but that it returns and there will be a victory of light over darkness, he recognized that particular day to be a most solemn occasion of the year, a day of grace, blessing, and joy. That day was the symbol of all bright and joyful hopes, heralding the glory of the coming springtime with its flowers and singing birds, the blessing of the new crop and food with the life-giving heat of summer days. The sun and its position in the sky was therefore of paramount concern to mankind since the earliest days of history.

Christmas, signifying the turning point and rebirth of the sun, was, therefore, worshipfully sanctified with many rituals which through the centuries have lost their meaning to the minds of those who mechanically perpetuated these inherited customs. The ceremonious burning of the yule log differs only slightly from the lighting of the Christmas tree, which represents the light to guide the Sun-god back to life. The

festival cakes of corn and fruit laid on the sacred altars of the ancient Egyptians and Persians as an offering of gratitude to the Lord of Life, through the train of symbolism relegated from civilization to civilization, has as its modern counterpart the burning plum pudding during our Christmas eve of rejoicing.

Star of Bethlehem

The light which is profusely used during yuletide festivities discloses in itself the solstitial nature of the observance. Space does not permit the presentation of the many curious customs of various nations both in Eurasia as well as among Pre-Columbian civilizations in America. Most of them, however, refer to a certain form of unusual star appearing in the sky at or shortly before the winter solstice event. The Advent Star, or in purely Christian language, the Bethlehem Star, was a phenomenal celestial light heralding the glorious event, the grace of God, the new Suntide.

In the words of W. T. Olcott: "The feast of rejoicing that a turning point in the Sun's course has been reached, the life giving orb has attained the end of its journey of menacingly dwindling hours of daylight and has started back on a course that brings with it each day an increase of warmth and light." The Advent Star of the ancient Egyptians was the famous Sothis, known today as Sirius, which heralded the coming of the Egyptian new year in its heliacal rise. The story of a star having a similar rôle was preserved through the ages. The Bethlehem Star heralding the birth of Christ is an outstanding example.

Our present civilization belongs to the Nordic race. When two thousand years ago the savages of the northland invaded and beheld Rome, even while destroying it, they became civilized. They fell under the influence of the Mediterranean civilizations of which Rome was then the only powerful representative. At that age the Nordic people already knew about the winter and summer solstice, celebrating with special emphasis the summer solstice as the principal public sun festival. Because of uninviting weather in the northland, the winter solstice was not convenient for public festivals. That is why Stonehenge, the famous sun temple built in England in the 17th century B.C., has its principal axis directed toward the point where the sun rises on the day of the summer solstice.

Link with the Past

The Mediterranean climate was not prohibitive to public gatherings during the winter solstice, however, and the sun festival of the Christmas season dominated events connected with the sun's annual rebirth, the sun's return northward in the sky. After their impact with Rome, the Nordic races gradually replaced their summer festival with the winter solstice festival, which is our Christmas. If, therefore, we observe that most churches in Europe have their principal altar facing the

rising sun, and keeping an eternal light which is extinguished only in the three symbolic Easter days, and above all, that they adapt the ancient solar thought to Christian allegory in a very plain Christmas service chant "Sol novus oritur" meaning "We celebrate the new Sun," we realize the definite link connecting us with ages past to an ancestry beyond recorded history. While its refining influence remains undisputed, Christianity represents a not too heavy super-position upon a remote and uncharted age of mythology.

The traces of this mythical age never can be effaced from mankind's experience anymore than our childhood can be separated from our individual adulthood. Something is mysteriously true about the fairytales of our childhood. We saw the same real world in the light of imaginations which had some distant image of reality, but they were the charm of our infancy. Similarly, myths as endless analogies are the soul of poetry, half-human stories filled with unfading life and beauty, masterpieces of art belonging to the past and in our age checked by the scrutinizing mind of the positivist philosopher and the scientist. Yet, despite the realism of our technical civilization, the ancient beauty and charm of Christmas will warm the hearts of countless people with a dream of a silent and holy night, the night of a great and glorious hope of a better future. This is the essential meaning of the most ancient heritage—the birth of light, the birth of Christ.

Shakespeare and the Stars*

By L. McCORMICK-GOODHART

It was a happy occasion, not so long ago, when our annual banquet was dignified by the presentation of the Stars and Stripes to our Society. Who does not esteem "Old Glory" not merely as a patriotic emblem of poignant historical meaning, but also as a simple piece of bunting; this not only by reason of the attractive arrangement of the colors but also by reason of 48 stars, instead, for instance, of 48 circles or 48 squares, having been chosen to represent the 48 States of the Union.

Now, by way of casting my humble Shakespearean bread upon the waters this evening, may I not start with a wager? However bold and presumptuous it may seem, I am willing to bet a silver dollar that no single individual among my listeners this evening can name, in their proper order, the states represented by each of the stars; or, in other words, name the stars! Or even tell me which state of the Union the very first star in the upper left canton of the National flag symbolizes! The moral of this is that many of us are brought face to face with the stars in the Stars and Stripes almost daily, but—they remain individually anonymous! Where is the Marylander or Virginian who can point

*Read April 9, 1945, before the Shakespeare Society of Washington.

to a particular star in the flag and say: "That is my star!" You good people of the District are out of court because you haven't reached your star!

But if this is true of "Old Glory," what of the majestic and illimitable heavens? How many of us can identify even one star in all that magic universe which surrounds us?

I deeply regret to say that a long experience has taught me that the ignorance of astronomy displayed by the man in the street (which, alas! also includes the woman in the home) is nothing less than devastating and abysmal. Not so long ago I was standing in a mood of rapture on my terrace at home, gazing wonderingly at the dark blue universe above. I was joined for a few moments by a young lady of some 30 years staying under our roof. I pointed to the moon—it was full that evening—and said "What causes the moon to be lit up?" She didn't know, possibly because she was a non-drinker! Then I asked: "Do you know the essential difference between a planet and a star?" She did not. I said "Can you tell a planet from a star?" She could not. God's universe around us and we ordinary people know it—not!

This evening we propose, without a telescope and without meeting in the open star-lit air, to cast our mental glances at the stars. But we are going to look at them from the mind's eye of another, not with our own. We are going to study the reaction of one of the very greatest minds of history to the greatest facts which our own minds can ever compass; the facts of the universe around us. We are going to consider the immortal Shakespeare as a star-gazer. A titanic man's reaction to a titanic universe!

Our first and safe assumption is that the illustrious dramatist occasionally directed his glances to the heavens, whether, it may be, in a romantic mood when courting Ann Hathaway at her cottage at Stratford; whether when in a tired mood as he sought the open air for what we call a "breather" while performing at the Globe; or whether on many other an occasion the heavens shone their scintillating rays upon him. Shakespeare, the greatest humanist, must have done a lot of wondering as to what the stars all about him in the heavens, were, in the vernacular, "all about." And, in keeping with the title of our discourse, since we could almost continue on the subject till the night wanes away, we must decide to omit entirely Shakespeare's countless references to those resplendent spheres we all at least are so familiar with—the sun and the moon. Therein lies enough material for another discourse, if not a book! True, the sun is a star but Shakespeare did not visualize it as such anymore than we do. He, in the ignorance of the day, considered the sun to be a planet and not only that, but a fixed planet. And he thought also that the moon was a planet! So let us keep both these familiar jewels of the sky out of our orbit tonight, except in one or two respects which follow later; and let us not romantically allude to "Phoe-

bus's Mansion" and Hyperion's "quickening fire," or to Juliet's "inconstant moon that monthly changes in her circled orb."

Shakespeare then, like all of us, gazed at the universe about him. But how much did the great dramatist know about it all? How much, as the science of astronomy then existed, could he know about the stars? Did he know relatively as much about the heavenly bodies as he knew of many other activities of nature and man; for instance, about the birds or about the sea, two subjects which I have already had the privilege of discussing with you in past years?

One of the commonest words in Shakespeare is the word "heaven." Amazing though it may seem, the word recurs over 800 times. But comparatively few of all these references may be said to bear on the physical heavens. As in "Love's Labour's Lost," might I not say in connection with this paper: "Study is like the heaven's glorious sun!" In the "Taming of the Shrew" we find a particularly beautiful expression: "What stars do spangle heaven with such beauty." In Second Henry VI we note an interesting reference to the Eternal Mover of the heavens. In the use of the word "mover" Shakespeare could only have had in mind the visible changes of location of the sun, the moon, and the then visible planets. Little idea had he that all his so-called "fixed stars" alluded to in "Richard II," also move in their mysterious celestial courses. In "Troilus and Cressida" he refers to "as many farewells as the stars in heavens." That, we feel, might well apply to a Prima Donna star!

It is curious how Shakespeare uses the word "universe" on only one occasion. In the prologue to the fourth Act of "Henry V" the chorus chant: "Now entertain conjecture of a time when creeping murmur and the poring dark fills the wide vessel of the universe." What a graphic picture of the beginnings of all creation!

The word "firmament" comes to us half-a-dozen times and in each case the reference is to the firmament in a physical aspect. One use of the word in "King Lear" contains an astrological bearing. In "Titus Andronicus" we find the interesting query: "Hath the firmament more suns than one?" There seems almost to have been suspicion in Shakespeare's mind that every star we see is in the nature of a sun.

The physical heavens are described three times by the word "vault." In the "Tempest" we read: "Twixt the green sea and the azured vault," and in Second Henry IV: "It stuck upon him as the sun, in the grey vault of Heaven." The word "canopy" is not used as a symbol for heaven, but once in "Hamlet" signifies the air around about us.

Shakespeare carries some forty references to the sky, as, *e.g.*, in "Two Gentleman of Verona": "The sun begins to gild the western sky" and in "King Richard II": "The sun will not be seen today; the sky doth frown and lour."

Let me say at once that there is no evidence that Shakespeare made any intimate study of the heavens, or was more versed in the progress

of astronomy than you or I. Shakespeare looked upon the stars much as you or I look upon them—as a countless collection of "twinkling pinpricks." In "Titus Andronicus" the poet refers with charming license to the "burning tapers" of the sky.

Yes, the stars of the heavens are anonymous except to the few. Shakespeare took the stars in the daily strides of his giant mind just as he took men in his myriad complexities, and the beauties of nature in its humbler forms. The heavens to Shakespeare were predominantly a source of dramatic inspiration. They were something apart from the ordinary human world which claimed his genius, too incomprehensible and too distant to worry about, except, for instance, as homes of the gods or as purveyors of good or evil fortune.

Let us turn to what the poet could have known about the stars. In other words, how far had astronomy progressed by the time the dramatist reached his prime? The results are more or less surprising because the ignorance of his times was amazing when judged by modern criteria—as amazing probably as our own knowledge in the present day, will appear to astronomers in 350 years' time, or say in 2300 A.D.

There is no more fascinating study in the whole realm of science than to trace the history of astronomy from the time of the early Babylonians, and to watch the torch of knowledge glowing ever more and more brightly as it was passed from one generation of astronomers to the succeeding one.

The beginnings of astronomy go back to the dawn of recorded history in Babylonia and China. We know the study of the stars goes back to well before 2000 B.C. in the latter country. But in China, only after some 4,000 years were the native methods influenced by new methods introduced from Europe by the Jesuits. From Babylonia, astronomy and its companion science, astrology, spread to Egypt, where astrolatry, or the active worship of the stars, was not long in developing. Also the idea embodying the signs of the Zodiac—or the arrangement of certain stars in the pretended shapes of animals—sprang originally from the Valley of the Euphrates. And then along in the 3rd Century B.C. came Greece with its illustrious Eratosthenes, and Hipparchus who flourished from about 150 B.C. to 125 B.C. and who made a catalogue of 1,026 stars and divided them, as we do now, into various magnitudes.

Hipparchus, called the "Father of Astronomy," was the first to make accurate observations of the stars of which we still have a record. His division of the Zodiac into 12 constellations or signs is still in general use. Hipparchus is further credited with being the discoverer of "precession," or the motion of the earth's axis in relation to the positions of the stars; and it was he who determined the periods of revolution around the sun of the five then known planets.

Nearly three centuries went by from Hipparchus to Ptolemy of Alexandria in Egypt, who flourished from 127 to 151 A.D. Ptolemy de-

scribed the earth as a sphere in the center of the heavens. "Though some say the earth turns on its axis, and truly this simplifies theory, yet," says Ptolemy, "it is ridiculous." Recognizing the earth as the center of all things and immovable, Ptolemy was at pains to work out an elaborate theory of epicycles and eccentrics, as they are called, to explain the apparent motions of the sun, moon, and planets, and summed up the knowledge of how to calculate eclipses.

Ptolemy ruled the astronomical thought of the next thousand years, except for the Arabs, who, when Europe in its political and spiritual upheavals, failed to pick up the threads left by the classic schools, held a sort of side-line torch burning until a few sparks flew over the Mediterranean and helped to kindle the new learning, or Renaissance.

The beginning of the modern science of astronomy dates from about 1500, one hundred years before Shakespeare. Its outstanding pioneer was Nicholas Copernicus, a Pole of Thorn in the then Prussian Poland, who died in 1543 and whose quatercentenary was widely celebrated recently. Copernicus's three famous immediate successors were Tycho Brahe, a Dane, who died in 1601, fifteen years before Shakespeare's death, Johann Kepler, a German, of Württemberg, who died in 1630, fourteen years after Shakespeare's death, and Galileo Galilei, an Italian, who died in 1642, twenty-six years after Shakespeare's death.

The great Copernicus, who is called the founder of modern astronomy, conceived the rising and setting of the sun and stars to be the consequence of a daily rotation of our earth upon an axis pointing toward the Pole Star, and that the earth and the five planets, Mercury, Venus, Mars, Jupiter, and Saturn (all that were known up until his day) revolved about the sun.

Tycho Brahe, the Dane, rejected the Copernican system, maintaining that the sun revolved around a fixed earth, though the planets revolved around the sun. Tycho was an indefatigable worker. He constructed his own observatory, made his own instruments, and collected an enormous medley of observations of an accuracy superior to anything that had gone before. The records of these observations were given to his friend and pupil, Johann Kepler. The observations of the planets, particularly those of Mars, permitted Kepler in 1609 to establish the three famous laws of motion that bear his name. Until his time it was universally assumed that the circle was the only perfect curve, and that with this idea of perfection it was unthinkable that the heavenly bodies could move otherwise then uniformly in circular orbits. Kepler verified that the planets move in elliptical orbits about the sun, and with the sun not in the center of the ellipse but at one focus. Kepler also verified that the nearer a planet to the sun, the more rapid its speed.

And finally Galileo, the Italian of Pisa, who not only proved that the sun itself rotates, but was also the inventor of the first practical telescope in 1610, only six years before Shakespeare died. Galileo was

born in 1564 and lived, as I have said, beyond Shakespeare's death in 1616, to 1642.

But though these were great advances, it is more than doubtful that they had penetrated the common mind of Europe. There appears to be no evidence in the plays of Shakespeare's having noted the results of the work of anyone of these four great pioneers. Not a single astronomer is mentioned by name throughout the works. The poet may have been a skeptic, or he may have been confused to such an extent by the various theories advanced as not to hazard expressions which might be ambiguous or criticizable; or, he, above all a portrayer of humanity, may have entertained but little interest in the elucidation of the mysteries of the unknown universe about him. But that Shakespeare's knowledge of astronomy was at least on a par with that of the average highly-educated man of that day is abundantly clear.

You will have noted that Shakespeare was a contemporary of three of the four astronomical geniuses I have just mentioned. Astronomical debate was, it can be assured, at its height all through the dramatist's life; extravagant theories, as to the movements particularly of the heavenly bodies, were being discussed with acerbity in many a university and learned institution on the continent and, it may well be surmised, also in Britain. The new astronomy itself was an exploding star, a "nova" as they are called by modern astronomers. Galileo's invention of the telescope in 1610—an instrument with a magnification no greater than 33 diameters, or about four times that of a service binocular on the bridge of a modern warship — was in the year of Shakespeare's "Cymbeline."

Newton's great law of gravitation had not been announced to the world. Only in Newton's time was it discovered that the stars are not fixed and that some vary in brightness periodically; nor had anyone evolved a method of measuring the distances of the stars. Double stars were unknown till the end of the 18th century.

Shakespeare, therefore, made his entrance onto the stage of astronomy at the beginning of a great new act. By which of the great theories in regard to the apparent movements of the heavenly bodies, meaning the sun, earth, moon, and planets, was he influenced? By the ancient Ptolemaic theory that the earth was the centre of all and fixed, or by the modern new-fangled theory of Copernicus that the sun was fixed, and that all other heavenly bodies revolved around it; both theories, of course, being equally fallacious?

The villagers of Stratford and London, when the sky was clear, gazed upon the same stars and planets as we do. But it is hard to think that they could identify any of the heavenly bodies except the sun and moon, probably the planets Mars, Venus, Jupiter, and Saturn, and an occasional comet considered ominous of events to come. But, on the other hand, and in contrast to the ignorance of the masses, there have through

all the ages existed those scholars and men of the deepest learning who have devoted their labors to the study of the heavenly bodies. We have then, on the one hand, the ignorant mass of the people and on the other, the professional astronomers and, be it said, professional astrologers.

But between these two there has always existed a body of generally well-educated, and godly men who have marvelled, with some curiosity, but not much knowledge, at the wonders of the creation outside the orbit of this world. Within the ranks of this fortunate band we shall, I think, find William Shakespeare. Shakespeare was no astronomer, not even an amateur. Nor was Shakespeare a professional astrologer, though throughout the plays he manifests a profound interest in that science, which is now, except to a comparatively few individuals, acknowledged, as it could hardly in the end not prove to be, a giant humbug. One may now go so far as to say that Shakespeare was a far closer student of astrology than he was of its parent science, astronomy.

It is of some interest to note that Shakespeare never uses the words "astronomy" or "astrology," though "astronomer" occurs twice, in "Troilus and Cressida" and "Cymbeline," in the latter case in the sense of astrologer. The word "astronomical," used once in a striking passage in "King Lear," where Edgar asks Edmund "How long have you been a sectary astronomical?" carries an astrological rather than an astronomical significance.

The early years of the seventeenth century witnessed one of the most important steps forward, the invention of the telescope by one Hans Lippershey of Magdeburg about the year 1600. Galileo in Padua, Italy, hearing of it, devoted his energies to improving upon it, and, as we have seen, constructed a telescope in 1610, six years before Shakespeare's death. With this famous instrument, he observed the sun-spots, noted the rotation of the sun, discovered Jupiter's moons and applied to them the descriptive word "satellites"; he also discerned appendages to the planet Saturn which Huyghens, a Dutchman, found later in 1650 to be the famous rings. Kepler, in his preface to his "Dioptrics," published in 1611, writes: "O telescope, instrument of much knowledge, more precious than any scepter! Is not he who holds thee in his hand made king and lord of the works of God? Truly all that is overhead, the night orbs with all their motions, thou dost subjugate to man's intelligence."

As a slight coincidence in connection with this paper I happened to read recently in the *Washington Post* a nice little poem signed Alice Moser "On Reading Shakespeare." It began:

> "Through the long *telescope* of time
> The single eye will find a pearl
> Rich, distinct and understood
> In pageants of an earlier clime."

Did Shakespeare ever hear of a "telescope," much less gaze at the stars through one? The poet certainly does not use the word in his last two plays, "A Winter's Tale" and the "Tempest." The former was

produced by May, 1611, and there is reason to believe that the latter was written in the same year and played on November 11, 1611. The old form of the word telescope, "telescopio," first appears in Galileo's correspondence after September 1, 1611, and the first mention in English according to the Oxford English Dictionary does not appear till 1619, three years after Shakespeare's death when a Mr. Bainbridge, in a work describing a recent comet, states "For the more perspicuous distinction whereof, I used the telescopium." So if Shakespeare ever heard of Galileo's telescope it must have been after his inimitable pen had ceased its fluency, that is, between 1612 and April, 1616.

Telescopes connote observatories, though the first observatories had no telescopes. We know that the first observatory for the study of the heavenly bodies was built in about 300 B.C. at Alexandria, in Egypt. The first observatory in Europe was set up in Königsberg, in about 1471. The first observatory which may be considered a prototype of modern observatories was set up by Tycho Brahe on the island of Hven in the Danish Sound in 1576. The renowned observatory at Greenwich, England, was not founded until 1675, by Charles II.

Shakespeare does not use the word "observatory" but he appears to have had in mind the word "observe" in the technical astronomical sense for, in the "Comedy of Errors," Adriana says in Act IV, Scene II, "What observation madest thou in this case of his heart's meteors tilting in his face." And in "Troilus and Cressida" we have "The Planets and this centre observe degree, priority."

I stated at the beginning I would spare you references to the sun and moon, with one or two exceptions. Let us consider, however, the poet's references to eclipses. Shakespeare refers on five occasions to eclipses of the sun and moon. Now the interesting fact is that between 1598 and 1614 there were three total eclipses of the sun and one annular eclipse, in or near the British Isles. There was an eclipse in 1598 which was total in Dublin and Edinburgh, but not in London. Another total eclipse took place in 1605, but the path again did not pass through London. Actually it passed southwest of Ireland. And again in 1614 the path of totality was a few hundred miles still farther southwest. The one annular eclipse (that is when the moon, being farther away, and consequently smaller in appearance, leaves a ring of sunlight around itself) could not in 1601 be seen in its fulness in London. Now the poet, in writing "King Lear," makes three references to eclipses in Scene II of the first Act. Gloucester remarks specifically to his bastard son Edmund: "These late eclipses in the sun and moon portend no good to us," and, later, "O! these eclipses do portend these divisions"; and Edmund counters, "I am thinking, brother, of a prediction I read this other day, what should follow these eclipses." Now "King Lear" was produced for the first time on December 26, 1606, and was, we believe, written during that year. Surely Shakespeare must have had in mind

the partial eclipse of the sun, which he saw on October 12, 1605! And, of course, lunar eclipses are seen far more frequently than solar, and Shakespeare must have observed many.

Let us now leave our brief visit to the sun and moon and cast our thoughts upon the planets. Believe it or not, even in Shakespeare's time it was thought there were only seven planets, all of which were thought to revolve around the earth, and two were the sun and moon! Of course the latter does revolve around the earth but as a satellite, not a planet. This leaves only five planets actually known to Shakespeare and his contemporaries, of the nine major planets known to us moderns. Of these, one, of course, is now the earth itself. In 1600 only Mercury, Venus, Mars, Jupiter, and Saturn (though not then known to possess its rings as we have seen) had been recognized. Uranus was not discovered till 1781. Neptune was discovered in 1846. And we probably all remember the discovery of Pluto in March, 1930.

Taking the word "planet," how many references do we find in Shakespeare? To be exact, seventeen, An analysis of these references gives interesting results. Eight of these have astrological significance; in other words, they bear on the planets' influence over men. Four appertain to the odd conception of a planet as a physical striking force as in "Titus Andronicus," "Some planet strike me down, that I may slumber in eternal sleep"; two relate to imagery, as "the Senate-house of planets," and others refer, respectively, to the position of a planet in space, to the sun as a planet, and to the moon as a planet—the latter two, of course, confirming the astronomical ignorance of the day—or perhaps I should better say, night!

The word "planetary," whose first use in the language we find in Shakespeare's time, 1593 to be precise, occurs twice, once in an astrological sense and once in the expression "planetary plague" which, as a plague coming down to us from a planet, we might well translate into modern language as "poison gas."

Taking the individual planets as the poet knew them, we find three references to Mars, that is specifically as a heavenly body and not as God of War. In "All's Well that Ends Well," Helena talks with Parolles: "Monsieur Parolles, you were born under a charitable star." Parolles: "Under Mars, I." Helena: "I specially think, under Mars." Parolles: "Why under Mars?" Helena: "The wars have so kept you under, that you must needs be born under Mars." You will note that the sense here is very distinctly astrological.

In the first part of "Henry VI," produced in 1592, the poet comes near to exhibiting a sign that he was aware of the great astronomical controversy begun by Copernicus and Tycho Brahe affecting the movements of the nearby heavenly bodies in a passage where Charles the Dauphin begins Scene II of the first Act with the words: "Mars, his true moving, even as in the heavens, so in the earth, to this day is not

known" which seems to indicate that Shakespeare did not know of Kepler's researches.

And in "Troilus and Cressida" the poet has Troilus refer to the red color of Mars: "In characters as red as Mars, his heart inflamed with Venus."

Turning to the planet Venus, Shakespeare refers thrice to its brightness in "Midsummer Night's Dream" and the First Part of "Henry VI"; once to its astrological import in "Titus Andronicus": "Though Venus govern your desires, Saturn is dominator over mine."

Shakespeare, in the Second Part of "Henry IV" makes a highly unexpected reference. Prince Henry remarks of Falstaff and Doll Tearsheet when they embrace: "Saturn and Venus this year in conjunction! What says the almanac to that?" I consulted a well-known astronomer on this point and he replied: "Unquestionably there was a conjunction between Venus and Saturn in 1597," the year in which "Henry IV" was written. But unfortunately I have been unable to trace the exact date of this interesting astronomical event. But for that un-Saturnine old fellow, Falstaff, it must have been an exhilarating conjunction!

Apart from the two references to Saturn already cited, one astronomical and one astrological, there is but one other reference to the planet and not the god, again astrological, in "Much Ado About Nothing."

For Mercury we have one astrological reference where Autolycus in "Winter's Tale" remarks of himself "who being as I am, littered under Mercury," etc.

There is as far as I can discover no astronomical or astrological reference to the planet Jupiter, though the name of that all-powerful god decorates the context some thirty times, but on the other hand, it is amusing to note that Shakespeare seems actually to have predicted the discovery of Neptune two hundred and fifty years later, when at the very beginning of "Hamlet," Horatio, Hamlet's friend, in making an historical comparison to Rome, exclaims "And the moist star upon whose influence Neptune's empire stands, was sick almost to doomsday with Eclipse." But even Shakespeare was not as great as that, and actually Horatio's expression refers to the moon's effect upon the tides!

Shakespeare was familiar with comets of which some are now and then visible to the naked eye. I remember some six years ago when summering in Massachusetts that two comets were seen by my family, of which one was conspicuous to the naked eye. Now Pericles which was, of course, part only Shakespeare's, was licensed for publication on May 20, 1608. In Scene I of Act V, acknowledged to be in Shakespeare's hand, Marina, protesting her innocence to Pericles, remarks "I am a maid, my Lord, that ne'er before invited eyes, but have been gazed on like a comet." Did Shakespeare have in mind the greatest comet of all, Halley's? For Halley's comet visited the earth in 1607, the year

previous to the publication of Pericles. One can't help thinking that he did. In the first part of "Henry VI" we have a rather delightful astrological reference to comets: "Comets, importing change of times and states, brandish your crystal tresses in the sky!"

Now let us turn to the vastly greater and even more wondrous realm of the stars. Who is there who realizes the enormous distances of the stars? The farthest of the sun's planets is Pluto, at a mean distance of three thousand, five hundred million miles. Yet the nearest star to us, except the sun itself, is over 7,000 times that distance, or 25 million million miles. When you consider that the sun's light takes about eight and one-half minutes to reach the Earth, and that the nearest star's light takes somewhat over four years, you obtain a concept of the size of the universe we live in. The light of some galaxies (or local universe outside our own) takes 100,000,000 years to reach us.

Shakespeare's use of the word "star" occurs in every play but four, and yet it cannot be said that the poet over-capitalized such a vast domain. The large and obvious sun and moon were for him subjects of vastly greater opportunities. There are in the plays some 200 references to the sun and about 120 to the moon, with only 60 to the stars. Of these latter about half refer to the fortunes of men as governed by them. The shining of the stars is frequently referred to.

Shakespeare twice emphasized the alleged belief in his era, of the fixity of the stars in their places. In "Richard II" we hear of meteors frightening "The fixéd stars of heaven." The other reference to "fixéd" stars is in "Love's Labor's Lost," as I shall mention at the end of this paper.

Now, to pick up one further reference made by the poet to the sun, we may ask: "Did Shakespeare know of sun-spots? After all, one feels that he might well have known of them since all of us have presumably gazed at sun-spots in our time by merely using a dark glass. In that interesting comparison with Rome in the first scene of "Hamlet," Horatio, in talking of the ghost, compares the appearance of the "sheeted dead" before the death of Julius Caesar, to "disasters in the sun." This is a physical reference since in the same sentence he also compares this preternatural happening to "stars with trains of fire" which expression forms strong evidence of Shakespeare's cognizance of comets.

And while we are thinking of comets the poet's works contain some ten references to meteors and the first use, apparently, in English literature of the expression "shooting star," in "King Richard II" (1593) as synonymous for meteor. These references have been examined and all would seem more likely to bear on the modern meaning of meteor, or shooting star, rather than, as has been suggested, on visible comets which, except for the rare appearances of Halley's comet, were few and far between. From three of the references it is evident that Shakespeare labored under the very curious impression, as presumably others

of his day did, that meteors were "exhaled" or, so to speak, breathed out by the sun!

It is worthy of note that Shakespeare mentions very few indeed of the individual constellations, and not one single star by its real name except the Pole star; the Zodiac, that mysterious belt of "little animals," outlined by various groups of stars, is only referred to once, well as it must have been known to the poet. In the one case, in "Titus Andronicus." the word is used in a transferred sense for the lapse of a year; "gallops the Zodiac in his glistening coach." Of the twelve signs, or, according to the Greek derivation, "little animals," in the Zodiac, the four we can definitely trace in the plays are Taurus, the Bull; Virgo, the Virgin; Aries, the Ram; and Cancer, the Crab. In "Twelfth Night" Sir Toby exclaims "Were we not born under Taurus?" Virgo, Aries, and Taurus all are mentioned in that curious and confused passage in "Titus Andronicus," Act. IV, Scene III, in a dialogue between Titus and his brother, Marcus, where the arrows are fired to solicit the gods to send justice down on the Earth. It is certainly odd that Shakespeare included these three signs of the Zodiac, or combinations of stars, amongst the gods—presumably only because all are in the sky! The fourth sign mentioned by the poet, Cancer or the Crab, secures one curious mention in "Troilus and Cressida." Ulysses in protesting to Agamemnon that Ajax should not visit Achilles declaims that such a visit would "add more coals to Cancer when he burns with entertaining great Hyperion."

The only constellations outside of the Zodiac mentioned are the Great Bear, in its Latin form Ursa Major, and Draco, the Dragon, both astrologically, in a remarkable passage in "King Lear." There occurs also a further evident reference to the Great Bear in the first part of "Henry IV": "We that take purses go by the moon and the seven stars," the Great Bear, as probably you all know, being made up of seven unusually bright stars.

And in the plays only two particular stars are mentioned. Shakespeare rather surprisingly neglected such conspicuous first magnitude stars as Sirius, Betelgeuse, Vega, Altair, and Aldebaran. But once does he appear to refer to Urania, goddess of the stars, where a passage in "Much Ado About Nothing" has: "Pardon, Goddess of the Night, Those that slew your virgin knight," etc. Not once does he refer, so far as I can trace, to the Milky Way which he must have gazed upon on many an occasion and whose name "Milky Way" was known in English as long ago as Chaucer's time, and well kown to the Romans as *Via Lactea*. Of the only two stars specifically defined, one, the "Eastern Star," is apostrophized by Chairmian as Cleopatra applies the asp to her breast, and the other is the "North," or "Northern Star," in each case a vague definition though for centuries prior to the poet both terms were synonymous with what we call the Pole Star, so vital to naviga-

tion, in the constellation of the Little Bear. And of special interest is that navigation at sea by the Pole Star alluded to in "Much Ado About Nothing," though in a figurative sense. Margaret exclaims to Beatrice "Well, and you be not turned Turk, there's no more sailing by the star."

Another reference to the Pole Star seems involved in the poet's only use of the word "zenith." In the "Tempest," Prospero, Duke of Milan, exclaims "I find my zenith doth depend upon a most auspicious star; whose influence if now I court not but omit, my fortunes will ever after droop." He plays up the word "zenith" which is as we all know the apparent highest point in the heavens above us. By "a most auspicious star" we must suppose the poet referred to the Pole Star nearly due above us but which is actually in the zenith only at the North Pole of our Earth.

So profoundly impressed were early astronomers or "star-gazers," as he aptly uses the word in a single passage in the poem "Venus and Adonis," by the marvels of the heavens that it becomes a natural step to conclude that the stars, in some occult manner or other, shaped human destinies. And so the astrologers had arisen—those who could in a few words tell a person's fortune from the state of the heavens at any particular moment. One recent writer describes the origin of astrology in this fashion. The Babylonians saw in the heavens seven objects whose positions were constantly variable—the sun, the moon, Mercury, Venus, Mars, Jupiter, and Saturn. Of these seven bodies, five behaved in strange ways moving eastward, then westward, sometimes slowly, sometimes rapidly. They moved according to whim, not according to rule. But only the gods could be whimsical, so the names of the principal gods were given to these moving bodies! Later, the powers of the gods were also transferred to the planets and, since the gods ruled mankind, the planets must perforce also rule mankind. This theory, vivid as it may be, is curiously borne out by a passage in "Troilus and Cressida" where Ulysses exclaims (Act I, Scene III), "But when the planets in evil mixture to disorder wander, what plagues and what portents," etc., "divert and crack the unity and married calm of states."

Shakespeare's references to the influence of the stars and planets on human events—astrology—are almost countless. For the word "star" alone, very nearly half the references bear on the control of men's fortunes by the heavenly bodies. Even nowadays people trace their fortunes in the same way. The other day at Union Station I found six different astrological magazines on one bookstall! The dramatist however never uses the words "astrologer," "astrology" or "astrological," though the first occurrences of these words in the language occurred in 1382, 1560, and 1591, respectively.

In "King Lear," Act IV, Scene 3, the Earl of Kent exclaims "It is the stars, the stars above us, govern our condition." Was not Kent here uttering the true belief of the creator of his part? In "Much Ado About

Nothing" occurs: "There was a star dancing and under that I was born." In "Love's Labor's Lost": "Thus pour the stars down plagues for perjury." In "All's Well That Ends Well": "We, the poorer born, whose baser stars do shut us up in wishes." In "Twelfth Night" occurs an expression we all use occasionally nowadays and one which proves us, possibly in spite of ourselves, victims of the astrological past—"I thank my stars I am happy." However, Shakespeare never said "Lucky stars." In "Titus Andronicus" we find "Was't not a happy star led us to Rome"—one of many of the great poet's sentiments that are profoundly applicable nowadays!

From a very interesting passage between Edmund and Gloucester in the First Act of "King Lear" an astute researcher of Shakespeare might deduce that the poet was not quite sure of his own astrological position, since after Gloucester's statement that the "late eclipses in the sun and moon do portend no good," Edmund counters "This is the excellent foppery of the world, that, when we are sick in fortune, we make guilty of our disasters, the sun, the moon, and the stars." As Professor Nicoll, the great authority on Shakespeare, has pointed out to me, is there any significance in the fact that the honest, worthy, if not too quick-witted Gloucester is made to believe in astrological influence, while skepticism —if not complete disbelief—is put into the mouth of the dishonest, unworthy, but intellectually acute Edmund? It may be that the great Shakespeare was hedging in his own beliefs.

In bringing this very brief and tentative treatise to a conclusion, let us see how we can summarize the immortal poet's appreciation of the physical heavens. My personal impression is that Shakespeare possessed what one may call a knowledge of the heavenly phenomena, carefully balanced in the treasure-chest of his knowledge of a thousand different subjects. But he possessed no more knowledge of the facts of the heavens than any well-educated man of his time might have attained to. There is but little trace, if any, of his having speculated in the astronomical theories being so loudly debated in his time. He makes no mention of any particular astronomer. There is no evidence that he knew any particular star by its then astronomical name except the Pole Star, though he was probably well able to point to the brightest planets. It is impossible to believe that he could not recognize some of the more conspicuous constellations such as the Great Bear and Cassiopeia.

In "Love's Labor's Lost," Act I, Scene I, Shakespeare even puts into the mouth of Berowne, talking to Henry of Navarre, words which may have expressed his own disinclination to study the stars more closely, or which may have conceivably been a hidden slap at Galileo and the other astronomers of the day:

> "Those earthly Godfathers of heaven's lights
> That give a name to every fixéd star
> Have no more profit of their shining nights
> Than those that walk and wot not what they are."

On the other hand, all through the plays there is manifested a deep and ceaseless wonder of the heavens. His mind was constantly in tune with the miracles of the universe and, above all, affords us abundant and incontrovertible evidence of his belief in what may be called the remote control of human events by a creator of whose omniscient and omnipotent existence he was profoundly convinced by the presence of the heavenly bodies in the sky.

As we bring these words to an end, we can perhaps hear Shakespeare himself speak as Helena in talking of her affection for Bertram in "All's Well That Ends Well": "I should love a bright particular star." We may, in our hearts and minds, agree that indeed the genius of Stratford does have "his bright particular star." Perhaps one of these days his own particular star will secure his name! Why not?

Sir Harold Spencer Jones
F.R.S., F.R.A.S.

"Whereas, in order to the finding out of the longitude of places for perfecting navigation and astronomy, we have resolved to build a small observatory within our park at Greenwich . . . with lodging rooms for our astromical observator and assistant, our will and pleasure is, that according to such plot and design as shall be given you by our trusty and well-beloved Sir Christopher Wren, Knight . . . you cause the same to be fenced in, built and finished with all convenient speed . . ."

It was in 1675 that King Charles II founded the Royal Observatory at Greenwich. From that time the most important astronomical research in Britain has been carried out at the Observatory. In 1884 an international conference agreed upon the Greenwich meridian as the world's zero of longitude, and also on a world time system based on Greenwich Mean Time.

The Astronomer Royal today is Sir Harold Spencer Jones, F.R.S. His association with Greenwich began thirty-two years ago, when he went down from Cambridge to become Chief Assistant to the Royal Astronomer of that time. He was born in London on March 29, 1890, went to school at Latymer Upper School, Hammersmith, and won a scholarship to Jesus College, Cambridge. There he took the mathematical tripos with a first class in both parts, followed by the natural science tripos, part II, for which he studied physics, again gaining a first class. He won the Smith's prize and was awarded the Isaac Newton studentship for research in astronomy and physical optics; in 1914 he held a fellowship at Jesus.

In 1913 he went to Greenwich, and remained there as Chief Assistant for ten years, during which time he worked chiefly on problems of variation of latitude, stellar photometry, the measurement of star dis-

tances, and the preparation of magnetic charts for the Admiralty.

Dr. Spencer Jones was appointed His Majesty's Astronomer at the Cape of Good Hope in 1923, and went out to direct the observatory there. Little was known at that time about the stars of the southern hemisphere and during the ten years that Dr. Spencer Jones spent in South Africa a program was begun which has since determined the distances of more than 1,200 stars, and the measurement of their proper-motions. The observatory made important discoveries about the way in which a star is born, when in 1925 a new star appeared in the constellation Pictor.

During these years Dr. Spencer Jones took the leading part in a great work which perhaps more than any other is associated with his name—the computation of the sun's distance from the earth. In 1928 the International Astronomical Union met at Leyden and asked him to preside over the Solar Parallax Commission.

It was known that the planet Eros would approach the earth in 1931, and observatories all over the world were asked by the Commission to cooperate in measuring its distance from the earth's center; with the data thus provided it would be possible to work out the sun's distance with a far greater accuracy than ever before.

The twenty-five observatories carried out their work from October, 1930, till May, 1931—the two photographic telescopes at the Cape Observatory secured the most important results—but the computations and calculations took ten years. These were carried out by Dr. Spencer Jones, and in 1941 he published the result. The distance of the sun from the earth is now estimated at 93,005,000 miles, with a margin of error of only 9,000 miles, the probable error "corresponding to the apparent breadth of a human hair at 10 miles."

For his work on the solar parallax Dr. Spencer Jones received the Royal Medal of the Royal Society and the Gold Medal of the Royal Astronomical Society. He was knighted in 1943. Long before the work was finished he was back in England, for in 1933 he was appointed to his present post of Astronomer Royal.

Sir Harold Spencer Jones has written a short history of the Royal Observatory, in which he mentions some of the developments which have taken place since his appointment to his present post of Astronomer Royal.

It was in 1936 that the Post Office instituted the first "talking clock," controlled by a signal each hour from the Royal Observatory, at the Holborn Telephone Exchange; Greenwich Mean Time is now available all over the country to people who dial "TIM" or ask for TIME. The Observatory has carried out research on the "fading" of short-wave radio transmissions which are caused, it has been found, by sudden bright eruptions on the sun's surface. Recently an "Air Almanac" has been produced, to assist airmen in air navigation, a companion service

to the "Nautical Almanac" originally produced by the Royal Observatory, and once again, since 1937, placed under its direction.

A big innovation is the introduction of quartz crystal clocks in place of the old pendulum clocks. Sir Harold himself is an authority on time measurement, and introduced one quartz crystal clock before the war; now the observatory is installing eighteen, of an improved design. These new clocks have been described by Sir Harold.

"Accuracy of time signals," he said, "has an increasing importance because of the enormous number of technical developments used by the Services." All the new electric devices depend on standardized frequency, the frequency being tested against time signals.

In the quartz clock a tiny rectangular plate, cut from natural quartz crystal, is set vibrating by an electric current. It is put in an airtight case, and kept at a constant temperature; the whole thing looks something like a radio set.

Special electrical devices had to be invented to count its vibrations. It vibrates 100,000 times a second, against the pendulum's once a second. Its signals go by special line to the B.B.C. each quarter hour and to the P.O. each hour; it is accurate within about one-thousandth of a second a day, as against the one to two hundredths of a second a day of a pendulum clock.

Since the war, for security reasons, the Royal Observatory time service has operated from two widely-separated and secret stations. It is probable that after the war it will not return to Greenwich, but will move to a new site, free from the electric and atmospheric disturbances which interfere with its work near London; the magnetic department moved to Leith Hill some years ago. Sir Harold will have the big task of installing it in its new home.

Sir Harold Spencer Jones was made a Fellow of the Royal Society in 1930; he is also a Fellow of the Royal Astronomical Society—he was their Secretary in 1923 and their President in 1937-9—and is an Honorary Member of the I.A.A.S. He was made an Honorary Fellow of his old college, Jesus, in 1933, the year he returned from the Cape. He is President of the British Horological Institute.

Sir Harold's publications include "General Astronomy" (1922), "Worlds without End" (1935), "Life on Other Worlds" (1940), and numerous articles and papers in scientific publications. He has also contributed several articles to "Science Looks Ahead" published in 1942 by Professor A. M. Low; one of them, "The Planets," gives in simpler form the substance of the Norman Lockyer Lecture which he delivered to the British Association in 1938. He describes the atmospheres of the planets, and the way in which they are photographed by ultra-red and ultra-violet rays.

Sir Harold Spencer Jones went on a lecture tour in 1943 to Spain and Portugal on behalf of the British Council. He gave the 1944-45

Christmas Lectures at the Royal Institution; this series of lectures is an annual feature, given for young people by a distinguished scientist. Sir Harold lectured to a large and enthusiastic audience of "children" of all ages.

The Planets in January, 1946

NOTE: Greenwich Civil Time is employed unless otherwise stated. To obtain Eastern Standard Time subtract 5 hours, Central Time, 6 hours, etc. The phenomena are described as they are to be seen from latitude 45° N. The data are taken chiefly from the *American Ephemeris and Nautical Almanac.*

Sun. The sun will again be moving northward and will advance from −23° 4′ to −17° 36′ during the month. Its motion eastward will take it from Sagittarius into Capricornus, through a region of the sky quite devoid of bright stars. There will be a partial eclipse of the sun on January 3. At maximum a little more than half of the sun's disc will be obscured. It will be invisible at Washington.

Moon. The phases of the moon will occur as follows:

	d	h
New Moon	Jan. 3	12
First Quarter	10	27
Full Moon	17	15
Last Quarter	25	5

It will be at perigee (nearest the earth for the month) on January 14 and at apogee (farthest from the earth) on January 26.

Mercury. Having passed a point of greatest elongation west on December 26, Mercury, at the beginning of the month will still be more than an hour west of the sun. It will move eastward more rapidly than the sun and nearly overtake it by the end of the month. It will, therefore, be invisible during most of this period. Its declination will be about the same as that of the sun.

Venus. Venus, like Mercury, will move eastward more rapidly than the sun. It will be in superior conjunction with the sun on February 1, and hence will be too near the sun to be observed during January. It too will be quite far south.

Earth. The earth will be at perihelion, nearest the sun for the year, on January 2.

Mars. Mars will continue a slow retrograde motion during this month in the constellation Gemini. It will be in opposition to the sun on January 14. This will mean that it will be above the horizon throughout the night. Its large northern declination will make its position still more favorable for northern observers. It will move from Cancer into Gemini, and at the end of the month it will be just south of the "Twins," Castor and Pollux.

Jupiter. Jupiter will continue to be the brilliant morning star. On January 17 it will be in quadrature, 90° west of the sun, and consequently it will rise about midnight on and near this date.

Saturn. Saturn like Mars will be in opposition to the sun about the middle

of the month. These two planets will be rather near to each other in the sky and will form in interesting pair of objects for amateur astronomers during this month.

Uranus. Uranus will cross the meridian a few hours before midnight. It will be in the constellation Taurus.

Neptune. Neptune will move back and forth over a very short arc in Virgo. It will rise a few hours before midnight and be in a position for observing in the early morning hours.

Occultation Predictions for January, 1946

(Taken from the *American Ephemeris*)

Date 1946	Star	Mag.	IMMERSION Greenwich C.T.	*a*	*b*	Angle E from N	EMERSION Greenwich C.T.	*a*	*b*	Angle E from N
			h m	m	m	°	h m	m	m	°
Occultations Visible in Longitude +72° 30′, Latitude +42° 30′										
Jan. 5	27 Capr	6.2	22 42.1	—0.1	+0.3	35	23 36.1	—0.7	—1.7	281
14	85 H¹Taur	6.0	0 34.9	—2.0	+0.3	95	1 43.2	—1.4	+2.0	220
14	234 B.Taur	6.0	3 19.5	—1.9	—2.3	118	4 13.4	—1.4	+1.8	210
14	ε Taur	3.6	5 26.1	..	..	143	5 55.3	—1.4	+2.9	195
15	o Taur	4.8	4 0.0	—1.8	—4.0	139	4 40.6	—1.8	+3.1	204
15	BD+22°925	6.5	5 40.3	—1.7	+1.7	33	6 21.4	—0.3	—3.5	319
Occultations Visible in Longitude +91° 0′, Latitude +40° 0′										
Jan. 5	27 Capr	6.2	22 39.0	+0.4	+2.2	8	23 16.3	—2.4	—3.2	306
14	85 H¹Taur	6.0	0 3.5	—1.1	+1.4	76	1 13.9	—1.3	+1.7	236
14	234 B.Taur	6.0	2 42.1	—2.5	—1.0	111	3 41.5	—1.4	+2.6	208
15	o Taur	4.8	3 25.9	—3.1	—4.3	141	4 0.7	..	..	192
15	BD+22°925	6.5	5 4.9	—1.8	+1.3	51	6 10.8	—1.4	—2.0	294
20	46 Leon	5.7	5 55.3	—1.7	+2.2	71	6 54.1	—1.2	—2.4	336
Occultations Visible in Longitude +120° 0′, Latitude +36° 0′										
Jan. 12	389 B.Ceti	6.3	1 14.9	—3.0	—0.9	114	1 55.8	+0.2	+4.0	177
13	85 H¹Taur	6.0	23 42.3	+0.1	+1.9	45	0 37.2	—0.8	+1.2	268
14	234 B.Taur	6.0	1 45.3	—1.1	+1.3	78	2 54.7	—1.2	+1.9	233
15	o Taur	4.8	2 21.9	—1.4	+0.6	104	3 20.4	—0.7	+2.6	219
15	BD+22°925	6.5	4 10.2	—1.1	+2.5	42	5 17.2	—2.4	—0.6	286
15	175 H¹Taur	6.5	10 9.6	—0.9	—0.8	80	11 10.8	—0.2	—1.3	280
20	46 Leon	5.7	5 21.4	—0.3	+1.4	84	6 22.4	—1.0	—0.3	310
26	o Libr	6.1	12 59.8	—2.4	+1.1	86	14 11.0	—0.9	—1.9	338
27	ν Scor *m*	4.3	15 26.7	—2.9	+0.4	83	16 48.2	—1.9	—2.0	324
Occultations Visible in Longitude +98° 0′, Latitude +30° 0′*										
Jan. 11	ν Pisc	4.7	5 45.9	—0.4	+1.5	26	6 31.0	—0.1	—1.7	287
13	85 H¹Taur	6.0	23 43.2	—1.2	+1.0	89	0 45.8	—0.8	+2.3	220
15	BD+22°925	6.5	4 43.6	—2.4	+0.1	85	6 7.6	—2.1	+0.1	255
15	175 H¹Taur	6.5	10 25.7	—0.2	—0.4	72	11 15.8	+0.4	—1.2	290
16	36 B.Gemi	6.0	0 11.3	—0.5	+0.7	98	1 8.6	—0.4	+1.9	237
16	BD+23°1491	6.5	10 57.0	+0.2	—1.9	129	11 43.9	—0.2	—0.3	246
18	γ Canc	4.7	7 18.0	—3.1	+2.0	61	8 16.6	—1.1	—3.7	336
20	46 Leon	5.7	5 34.9	—1.3	+0.1	112	6 54.8	—1.9	—0.3	292
26	o Libr	6.1	14 16.9	..	..	43	14 40.2	..	..	15

*Computed by Edgar W. Woolard and Paul Herget; communicated by Commodore J. F. Hellweg, Superintendent U.S. Naval Observatory.

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b;* apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

Last month the records sent in for the weeks which cover the Perseid and Delta Aquarid epochs were published. As these were quite long, their discussion was put off until this month. Meantime we have received belated reports for 1945, and, at the same time, we now add some reports for former years that indeed arrived in July but were unintentionally left out of last month's table. All of these will be found below.

Station and Observer	Dir.	Date	Began	Ended	Time	Min.	Met.	Fac.	R.	Ob.	C
Missouri		1941									
Rankin											
Brueggemann, H. P.	S	7 26	14:00	15:30	CWT	90	44	0.8	29	1	P
Friton, Mrs. E. E.	SSW	7 26	14:13	15:38	CWT	85	26	0.8	18	1	P
"		8 16	11:29	12:00	CWT	31	2	...	..	1	P
Webster Groves											
Friton, E. E.		7 26	14:13	15:38	CWT	75	13	0.8	10	1	P
Rankin		1943									
Ellison, Miss B.	S	7 25	10:48	12:05	CWT	77	8	0.6	6	1	
Friton, E. E.	S	7 25	11:00	12:00	CWT	60	3	0.6	3	1	P
Friton, Mrs. E. E.	S	25	10:48	12:05	CWT	77	8	0.6	6	1	
Kirkwood											
Friton, E. E.	SE	8 12	15:30	17:00	CWT	90	17	0.7	11	1	P
Friton, Mrs. E. E.	SE	12	15:30	17:00	CWT	90	17	0.7	11	1	
Osage Hills											
Long, Miss E.	SE	8 12	15:30	17:00	CWT	90	87	0.7	58	1	
Kirkwood		1944									
Friton, Mrs. E. E.	SW	8 10	10:47	12:30	CWT	103	8	0.9	5	1	P
Long, Miss E.	W	8 10	10:30	12:40	CWT	130	34	0.9	16	1	
Osage Hills											
Friton, E. E.	S	8 10	11:00	12:30	CWT	90	17	0.9	11	1	P
Webster Groves											
O'Byrne, S. L.		8 10	8:55	9:55	CST	60	10	1.0	10	1	P
Illinois											
Chicago		1945									
Anderson, R. F.		8 11	12:01	15:01	CWT	180	91	1.0	30	1	PC
"		12	11:00	13:05	"	125	25	1.0	12	1	PC
Pennsylvania											
Lake Como											
Epstein, E.		8 9	9:53	10:15	EWT	22	5	0.8	14	1	P
"		10	9:10	9:55	"	45	15	1.0	20	1	P
Huntington Park, Philadelphia											
Liss, Aaron		7 11	10:30	12:10	EST	100	18	1.0	11	1	D
"		8 9	10:	14:50	"	290	110	1.0	23	1	D

Station and Observer	Dir.	Date	Began	Ended	Time	Min.	Met.	Fac.	R.	Ob.	C
State College											
Schilling, J. H.	8	3	12:00	14:20	EWT	140	28	1.0	12	1	P
"		9	11:40	12:58	"	78	5	1.0	4	1	P
"		11	11:35	12:45	"	70	6	0.5	5	1	P
New York											
Bronx											
Waldmann, Ed.	8	4	10:30	15:20	EWT	288	33	1.0	7	1	D
"		8	12:00	13:15	"	75	13	1.0	10	1	D
"		9	10:10	11:30	"	80	3	0.9	2	1	D
"		10	10:48	13:00	"	132	16	1.0	7	1	D
"		11	9:59	16:40	"	401	112	1.0	17	1	D
"		13	10:19	11:19	"	60	6	0.5	6	1	D
"		14	11:08	12:08	"	60	5	0.7	5	1	D
"		15	10:20	12:20	"	120	13	0.5	6	1	D

Returning now to the general discussion, it is quite plain that the Perseids in 1945 furnished an excellent shower so far as numbers of meteors went, but I believe there were fewer conspicuous ones than might have been expected from such large totals. However, the return was heartening in that it indicated there are no real proofs that this most regular and rich of all annual showers is dying out. So far as these records go, they emphasize that old fact that really clear skies are necessary for success with meteors. Those persons who had them secured fine rates; people without them—in which category fall the writer and most observers around Philadelphia—had from fair to miserable luck. But our bad fortune was the fault of the weather and not the Perseids, so we will discuss the late return in view of the reports from the favored localities as they alone give the true picture.

Outstanding is that from Lieut. R. J. Wood, USNR, an A.M.S. member who has taken an active part for several years. He was on the *U.S.S. Pine Island* off Okinawa, the war was raging, the ship was under darkened conditions and the crew on alert. Despite the strain of expecting Jap planes at any moment, and other factors hardly ideal for scientific work, Lieut. Wood seems to have broken all records (at least so far as I can recollect) for numbers of Perseid and other meteors recorded on two successive August nights. A résumé of his data follows:

Ship in $\lambda = 127° 54'$ E, $\phi = 26° 26'$ N; GCT used (correction to local standard —9 hours).

1945 Aug. 11/12 F = 1.0			Aug. 12/13 F = 0.8		
11:28 to	12:00	8	13:20 to	14:00	27
12:00	13:00	21	14:00	15:00	92
13:00	14:00	37	15:00	16:00	81*
14:00	15:00	52	16:00	17:00	128
15:00	16:00	64	17:00	18:00	134**
16:00	17:00	121			
17:00	18:00	189	Total		462
18:00	19:00	153			
Total		645			

*25 minutes out.
**17:30 clouds rising.

Of this total count of 1107 meteors, 117 were plotted on maps and fully recorded on the standard blanks. Also 6 of the most brilliant, which left trains, had the latter studied with binoculars. Though none lasted a full minute, in at least one case drift was detected but no drift for the other five. The maximum

rate of 189 surpasses any A.M.S. record.

Another fine report is from John M. Henchman, U. S. Forest Service, Angeles National Forest, La Canada, Calif. His station was 3.2 miles S.W. of Mt. Wilson and, I presume, at a considerable altitude. These are counts only, made on Aug. 12/13, F = 0.9 on an average. P.W.T. was used.

10:30 to	11:30	66
11:30	12:30	76
12:30	13:30	102
13:30	14:30	126
14:30	15:30	100
Total		470

A third excellent report is from Wm. S. McNeill, a World War II veteran, observing 2 miles from Charlottesville, Va., where the elevation is about 500 feet above sea level. These are counts only. E.S.T. is used.

		Aug. 10/11 F = 1.0	Aug. 11/12 F = 1.0	Aug. 12/13 F = 0.8
11:00 to	12:00	37	45	31
12:00	13:00	41	51	34
13:00	14:00	47	59	22
14:00	15:00	33	47	25
15:00	16:00	28	41	26
16:00	17:00*	22	33	16
Totals		208	276	154

*It is obvious that dawn must have interfered this last hour on each night.

It would appear that the maximum came in Virginia, $\lambda = 78°$ W, $\phi = 38°$ N, between 13 and 14 hours, which would be in Greenwich Civil Mean Time Aug. 12 between 6 and 7 hours. These results are particularly valuable for they were made over the same hours for three nights in succession, thus giving a picture of the stream which we rarely get.

A fourth fine report is from Miss Margy Bidlake, a student, Pullman, Wash. She observed on Aug. 9 to 13 inclusive except Aug. 11 which was totally cloudy. Her results which are counts only follow. We *presume* P.W.T. was used, and that F = 1.0 on three nights.

		Aug. 9/10 F = 1.0	Aug. 10/11 F = 0.4?	Aug. 12/13 F = 1.0	Aug. 13/14 F = 1.0
10:00 to	11:00	33		47	48
11:00	12:00	36	13*	54	60
12:00	13:00		6*	62	63
13:00	14:00			59	62
Totals		69	19	222	233

*Vision partially impaired by clouds.

The rates on the last two nights, particularly Aug. 13/14, are unexpectedly high and indicate that at her station sky conditions must have been excellent so that fainter meteors than usual were visible. The altitude of her station is unknown to me. Again these observations, made night after night, are just the type which permit a proper evaluation of the strength of the stream.

The other reports were sufficiently analyzed last month except in cases where this was not possible, due to the whole night's count only being given, not results

for separate hours. The writer knows of a few persons who observed but have not yet submitted their records. These latter will appear therefore about a year late, when the 1946 Perseids are discussed. Of course a good many radiants for the Perseids and also of various minor streams will be found on the maps, when these are properly studied—a thing I have been as yet unable to do.

In general we had good response this year to our appeals for observations. Many of the reports were models of clearness and accuracy. As I intend to distribute these Notes to all who aided us, the following comments are in order. On future occasions always please state: what sort of time you used, the condition of the sky, what direction each person was watching, and exactly how many persons took part in the counting. Further, cannot the idea be established that what we want is a *separate count by each observer!* Each has no business paying any attention to what others do. We do not want group counts as they cannot be clearly analyzed. If there are ten people present and every one of the ten sees the same meteor, *each* should count it in his total. It makes no difference whether the others saw it or not: the only unit we can use is how many meteors one person sees per hour. Do try to get this simple matter straight in future counts. It is indeed wise to have people face different ways, but even then meteors will often cross from the region assigned to one person to that of another. Each must count it in his total! This does not mean that group counts are wasted or valueless, it only stresses that, if the counts were made individually, they would be much more valuable. It is no more trouble to do it the right than the wrong way, if only it is understood what is wanted.

To every reader, whether he took part on past occasions or not, we hereby call attention to the need of his cooperation next August and, for that matter, for many years to come. Only thus will certain problems of meteoric astronomy, dealing with the principal streams, be solved. We again express most sincere appreciation for past assistance and hope that our many collaborators, as well as A.M.S. members, will take a full part in the 1946 Perseid campaign.

A.M.S. members are requested to pay their dues before Jan. 15. Please do this without forcing me to waste time and postage sending bills. Any person desiring to join the Society is invited to write me on the subject. Many states still have no active members, others far too few. We would like to have all persons, really interested in meteors, enrolled in the A.M.S.

Flower Observatory, Upper Darby, Pa., 1945 November 8.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD
Department of Astronomy, University of California, Los Angeles 24

On the Spectrum of the Solar Corona

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ABSTRACT

Attention is called to the recent explanation of the line spectrum of the solar

corona. Most of the lines have been ascribed to highly ionized atoms of iron and nickel.

There exist energy levels in atoms and molecules from which all transitions downward are relatively improbable. These energy levels are referred to usually as "metastable," and the transitions downward are referred to as "forbidden" transitions. The radiation which is emitted by an atom which makes a forbidden transition is referred to usually as a "forbidden" line.

The lifetime of a metastable atom or molecule can be very long compared with that of an atom or molecule in states from which "permitted" transitions are possible. While the lifetimes of the atom in states from which permitted transitions are possible are about 10^{-7} second, one finds lifetimes of seconds, minutes, and even days for states from which some of the best known lines of nebular and upper-atmospheric spectra are emitted. Such famous lines as the nebular lines of neutral and ionized oxygen, carbon, and nitrogen atoms, the famous green auroral line at λ 5577, and the Vegard-Kaplan bands of N_2 are examples of forbidden radiations which have become important tools for the study of phenomena encountered by astrophysicists and students of the upper atmosphere.

The recent successful identification of the lines of the solar corona by the Swedish physicist, B. Edlén, has added another important source to the list of those whose principal radiations are accounted for by forbidden transitions. Most of the emission lines in the solar corona have been explained by assigning them to forbidden transitions from metastable states of iron, nickel, and calcium atoms which have been ionized many times. The strongest and most famous coronal line, at λ 5303, is emitted by 13 times ionized iron, from a metastable state which has a lifetime of about 60 seconds. Most of the lines are accounted for by iron and nickel.

The problem of the explanation of the presence in the corona of iron and nickel in such highly ionized states, and of the excitation of these atoms, is a fascinating one, and one which should interest the meteoriticist. The fact that most of the lines can be accounted for by iron and nickel leads naturally to the hypothesis that the solar envelope is bombarded by meteoritic matter, which is then ionized and excited by collisions with particles present in the corona. Altho this hypothesis would be a simple explanation of the origin of the coronal lines, serious objections can be raised against it, but these will not be discussed here.

Several other hypotheses have been advanced to explain the origin of the excitation in the Sun. Among these is the suggestion by M. N. Saha that the ions of iron and other metals are produced in some kind of nuclear reaction, similar to uranium fission, occurring at some depth below the chromosphere. There are arguments against this hypothesis, one of which is the rarity of the heavy elements in the Sun. Much new work remains to be done before the puzzle of the solar corona is entirely solved. An excellent review of the problem of the identification of the line spectrum of the solar corona has recently been written by P. Swings.[1]

REFERENCE

[1] *Publ. Astron. Soc. Pacific*, **57**, 117-37, 1945.

Thoughts on Exploring the Moon

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ABSTRACT

It is suggested that attempts may soon be made to send rockets to the Moon and that eventual success may be achieved. The writer believes that we shall not have to wait for the hazardous transportation of human cargo in order to begin lunar exploration; he believes that by attaching suitable explosives to rockets directed by remote control, fragments of lunar rock may be dislodged with sufficient violence to project them into the sphere of terrestrial gravitation and to cause them to arrive upon our planet. By means of world-wide networks of observing stations, the landing particles could perhaps be located, collected, and studied.

Now that atomic power and the principles of jet propulsion and rocket power are all realities, we may confidently expect that many engineers will exercise themselves with the problem of sending a rocket to our nearest cosmic neighbor—the Moon. Considering the advances that have been made in the field of electronics, I believe that it is not unlikely that controls can be developed by means of which such a missile could be steered by remote control to a point where it would be able to free itself from the gravitational influence of our planet and arrive on our satellite. That any rocket shall carry human cargo to the Moon is a question which may yet worry *Homo sapiens* for a good long time, but the exploring of our satellite need not wait on the complex and more difficult problems which are involved in the transportation and protection of human life on such a perilous journey.

The Moon is very completely under the control of our planet, and it is quite likely that any bombardment of it by man could be fairly easily studied, both by observations thru telescopes and by the more substantial laboratory techniques. Any particles which might be detached from the Moon by bombardment with sufficient force to have an initial velocity of as much as 1½ miles per second would be likely to leap so far out into space that they would escape its gravitational influence; and, since the bombardment would be most likely on that portion of the Moon's surface facing the Earth, some of these escaping fragments would, almost certainly, come under our own planet's gravitational control. This fact means that if they can survive atmospheric passage, some lunar substance is going to be deposited upon our soil. Such lunar particles should reach our outer atmosphere with velocities of about 7 miles per second. At such velocities, the particles would not experience the violent treatment imposed by our atmosphere upon true meteorites, whose velocities of encounter average almost 4×7 miles per second. A body traveling only 7 miles per second would be sufficiently cushioned by the outer atmosphere so that probably the denser layers near the Earth's surface would not prove to be so devastatingly destructive as they do in the case of most invading meteorites. Indeed, there is convincing evidence that meteorites which overtake the Earth in its 18½-mile-per-second flight around the Sun are dealt with far less severely than are those which arrive in head-on collisions with our planet.

When rockets shall be sent to the Moon, the attachment of some kind of atomic bomb capable of exploding without the assistance of the atmosphere should

be certainly sufficient, first, to produce a disturbance of such magnitude as to be observed effectively from the Earth, and, second, to dislodge fragments at velocities great enough to make possible a contribution of lunar material to our planet. Those who are familiar with my views on the origin of tektites[1] and who read this article will have already guessed, and correctly, that I am predicting that the fragments of lunar rock thus thrown our way will arrive as glassy objects similar to those which are now being picked up in Australia, Indo-China, the Philippines, southeastern Texas, the Isle of Billiton, and a few other places in the equatorial zone of our planet. When the first such rocket is fired, it will be possible to calculate with a considerable degree of accuracy the time at which any dislodged fragments should arrive in the Earth's atmosphere. There should be a large and widely distributed group of observers watching for these arrivals. Probably the arriving fragments will not sputter and sparkle as do most meteorites, but will develop a visible glow and be seen to travel at a much less rapid rate than we are accustomed to observe in the case of almost all meteorites. I should like to secure one of these new arrivals, to verify my hypothesis regarding the origin of tektites!

REFERENCE

[1] H. H. Nininger, "The Moon as a Source of Tektites," *Sky and Telescope*, **2**, No. 4, 12-15, and No. 5, 8-9, 1943.

Notes of Meteoritical Interest from "Texas Observers' Bulletin"

The following two notes of meteoritical interest have recently appeared in *Texas Observers' Bulletin* (edited by Mr. Oscar E. Monnig, a Councilor of the Society for Research on Meteorites), of Fort Worth, Texas.

"MORE METEORS—AND METEORITES!

"A sunset fireball near 7:30 P.M., C.W.T., Sep. 17, 1945, moved from northeastern Texas across into southeastern Oklahoma and dropped meteorites at Atoka, Atoka County, Oklahoma. If you have an accurate observation of this, or know of anyone who photographed the cloud or train left, by all means write us. Sanders and Monnig made a preliminary trip of investigation 3 days after the fall, and a report will be given in detail in the next *T.O.B.* [No such report is contained in *T.O.B.*, No. 167.] Investigations have been going forward also on a bright meteor reported from Fort Worth, 1945 Aug. 24, 10:55 P.M., C.W.T., by A. W. Mount."—No. 166, p. 4, 1945 Oct.

"TEXAS STATE HIGHWAY DEPARTMENT COUNTY ROAD MAPS

"Amateur astronomers often need accurate knowledge of the latitude and longitude of observing stations. Some like to have this information even tho it is not essential. It is necessary to have it precisely in occultation work or in rigorous work on meteor real heights. In various other computations it is needed with reasonably close accuracy, such as figuring times of sunrise or sunset, moonrise or moonset, or transforming coördinates from right ascension and declination to altitude and azimuth. It has also been recommended that locations of all new meteorites (either 'finds' or 'falls') be given by a coördinate number expressing latitude and longitude position [see Frederick C. Leonard, *C.S.R.M.*, **3**, 153-5; *P. A.*, **52**, 306-7, 1944, and the sources referred to therein].

"Maps giving geographical coördinate networks suffice for close approximations in most cases. The Rand-McNally series of State maps, generally available

from office-supply and book stores, for 50c each, are particularly good in this respect. But for closer figures, one must resort to triangulation surveys and reports concerning them, and even these are not always sufficient. A number of primary triangulation nets have been run across Texas, but many important regions are not yet included. It was not until 1935, *e.g.*, when an arc was being run from Jacksboro to Texarkana, that a loop was run down to Fort Worth to give us a number of modern, precise points in this region.

"In Texas areas where such data are not available, try the County Road Maps issued by the Texas Highway Department, State-wide Highway Planning Survey, Austin, Texas. The cost is $1.25 a map on those of full scale, generally 1 inch to a mile, and 75c each on the 'half-scale' maps, generally 1 inch to 2 miles. There are reductions in prices for quantities of more than 2 maps. A descriptive sheet and list of maps will be sent on request, so that you can order those which fit your territory and purpose best. Remittances must be by money order or check only, payable to the Texas Highway Commission, which will fill orders very promptly. Altho these are essentially road maps made originally about 1936-37 to show *all* public roads, they include a host of other information and indicate locations of most houses and buildings in rural districts. A latitude-and-longitude net is printed on each map, and positions can be read off by interpolation. Incidentally, the writer has found these maps invaluable in field work on meteorites." —No. 167, p. 2, 1945 Nov.

President of the Society: LINCOLN LA PAZ, Department of Mathematics and Institute of Meteoritics, University of New Mexico, Albuquerque

Secretary of the Society: C. H. CLEMINSHAW, Griffith Observatory, P. O. Box 9866, Los Feliz Station, Los Angeles 27, California

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VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Annual Meeting of the A.A.V.S.O.: The 34th Annual Meeting of the A.A.V.S.O. was held at the Harvard Observatory on October 5 and 6, 1945. With the easing of gasoline and travel restrictions, members from distant points were able to be present. They came from as far north as Quebec, from Florida in the south, Maine in the east, Wisconsin in the west, and from stations in between. Some 70 members and guests were present at the different sessions.

The Council met at 4:00 P.M. on Friday and, following the serving of tea, proceeded to elect new members, deal with the annual budget, and discuss revisions to the constitution and by-laws. Through the generosity of the new "Old Guard," the sum of $100 was raised to defray the cost of printing Mr. Rosebrugh's Index to Variable Comments, Volumes I, II, and III.

Four new life members and ten new annual members were elected. It was decided to increase the annual and life membership fees, final action to be taken at the 1946 Spring meeting. The invitation of Dr. Marjorie Williams to hold the next spring meeting at Smith College was gratefully accepted. The life of the Auroral Committee was extended through 1950, in order to cover the ap-

proaching sun-spot maximum.

On Friday evening, the Association was again the guest of the Bond Astronomical Club at its annual meeting. Professor Fred L. Whipple of the Observatory staff spoke on "Meteors in the Upper Atmosphere," a talk which was not only informative, but also highly interesting.

The regular business meeting of the Association was called at ten o'clock Saturday morning. Reports of officers and committees were received and eulogies paid to those members who had died during the past year. These included Mrs. Charles W. Elmer, Richard Prager, James M. Baldwin, John H. Ingham, and Chester A. Mowry.

The Recorder's report indicated an increased annual receipt of observations, which included communications recently arrived from Greece. A total of 34,244 observations was received during the year from 79 observers, including 22 foreign contributors. Mr. Fernald of Wilton, Maine, again headed the list, with 7,216 observations to his credit, a new high for one observer in any one year. He was followed by Mr. de Kock of Capetown, with 3,496, whose splendid work has been mainly responsible for keeping up the continuity of the light curves of the far southern variables. Next in order came Holt of Amherst, Mass., Peltier of Delphos, Ohio, Rosebrugh of Waterbury, Conn., Oheim of New Braunfels, Texas, and Focas, of Athens, Greece. Nine members contributed between 500 and 1000 estimates each; thirteen, between 250 and 500; while thirteen others made between 100 and 250 observations. South Africa contributed 4,577 observations; Greece 1,750; South America 1,664; Canada 1,427; India 430; and Australia 359. The 57 American observers contributed 23,934 observations, or 70 per cent of the whole, distributed among 22 states and the District of Columbia. A grand total of 978,244 observations has been accumulated during the past 34 years. The one million mark should be reached in the coming year. Who will be the observer to make that one-millionth observation?

The telescope department has been augmented during the year by the gift, from Professor Julian L. Coolidge of Cambridge, Mass., of a splendid six-inch Clark refractor.

The work of the Occultation Committee, under the direction of Professor Alice H. Farnsworth, showed continued activity.

The newly-formed Solar Division, under the leadership of Mr. Neal J. Heines, certainly has a fine record to its credit. Since its inception one year ago, 62 persons from 20 states have joined its ranks. The work of the division includes studies of solar granulation, prominences, and spicules, besides numbers and areas of sun-spots and sun-spot groups. Much of the work proved to be of great value to the Department of Terrestrial Magnetism of the Carnegie Institution at Washingon, as well as to other institutions. Members of the Solar Division Committee are Neal J. Heines, Chairman, Donald H. Menzel, Reverend and Mrs. W. M. Kearons, H. H. Clayton, and H. B. Rumrill.

The annual election of Council members for two years resulted in the selection of Lewis J. Boss and William L. Holt for a second term, and Ralph N. Buckstaff and Neal J. Heines as new members. Officers for the coming year are to be: President, Charles H. Smiley; First Vice-President, Marjorie Williams; Second Vice-President, David W. Rosebrugh; Secretary, Herbert M. Harris; Treasurer, Percy W. Witherell; and Recorder, Leon Campbell.

The Saturday afternoon session was given over to the presentation of papers.

Dr. H. H. Clayton spoke at length on sun-spots and the weather. Mr. David W. Rosebrugh discussed the results of his observations on the same star with different optical aids. Mr. Joseph Ashbrook described the light changes of the historic nova of 1670, which appeared in Vulpecula. A lengthy paper was presented by Mr. J. C. Bartlett, Jr., on Solar Granulation. Mr. J. J. Neale spoke on the observation of occultations on the bright side of the moon in a bright sky. Mr. James Stokley gave an interesting résumé of his work on the solar eclipse of July 9th, when he attempted to measure the brightness of the sky during totality. Mr. Cyrus Fernald gave many valuable suggestions on observing methods. Following adjournment, tea was served by the Observatory staff.

More than three-score members and friends gathered in the evening at the Harvard Faculty Club for the annual banquet of turkey and the fixings. The newly-elected President, Professor Smiley, acted as toastmaster, and called upon several old and new members for remarks and comments. The usual "Highlights," given annually by Dr. Shapley, had to be omitted because of his enforced absence. This was only the second meeting in over twenty years which Dr. Shapley had been obliged to miss.

The meetings adjourned following the banquet, to gather again at Smith College in the spring of 1946.

The Missing Maximum of SS Cygni: Over the almost fifty years during which SS Cygni has been under continuous observation, only one maximum—as far as we can conclude—had been missed, and that was in February, 1941, when the star was unfavorably placed for observation except for observers in high northern latitudes. It was hoped that some variable star observer in Denmark, associated with the astronomical sociey which has been mainly responsible for such observations during the months of February and March, would have observed the star at the time of the suspected maximum. Sure enough, in a recently received copy of the *Nordisk Astronomisk Tidsskrift* appears one lone estimate of SS Cygni, by J. Bull, on J.D. 2430051.32, at magnitude 8.7, which definitely indicates the occurrence of a maximum late in February, 1941. Once again we are reminded of the value of an isolated observation, especially on the irregular variables. Congratulations to Mr. Bull on his achievement!

Some Little-Known SS Cygni-type Variables: A publication recently received from the Royal University of Bologna, Italy, contains some important information on the lesser-known, fainter SS Cygni-type variables as discussed by L. Rosino of the astronomical station of Loiano. The work was on the basis of his own photographic observations, combined, where possible, with published observations. There were eleven such variables on his observing program, which includes some of the so-called Z Camelopardalis type, which type is closely associated with the SS Cygni variables. The list comprised EY Cygni, AB Draconis, FS Herculis, AY Lyrae, CY Lyrae, CZ Orionis, RU Pegasi, UV Persei, TZ Persei, SU Ursae Majoris, and TW Virginis. Rosino shows that FS Herculis, which originally had been classed as one of the SS Cygni type, is definitely a Cepheid, with a period of $6^d.150$, and a mean amplitude of 1.4 magnitudes. For EY Cygni there appears to be little evidence of marked variation, in fact in the absence of well-confirmed observations brighter than magnitude 15, no maxima have been observed in recent years. The star requires still further watching by observers with large telescopes.

Rosino's observations of AB Draconis are well substantiated by the con-

temporary AAVSO visual estimates. The minimum magnitude appears to be near 15.5, according to the photographic observations.

AY Lyrae has a large range, between magnitudes 12 and 17, with narrow and wide maxima. SU Ursae Majoris, varying between magnitudes 12 and 15, is one of the shorter cycle SS Cygni-type variables.

The light curve of RU Pegasi, with photographic and visual observations in good agreement, shows some resemblance to that of SS Cygni, but with an amplitude of variation of only two magnitudes, with cycles rather long for a star of such a small range, and the absence of rapid increase to maximum.

CY Lyrae is a typical SS Cygni-type variable, range of about three magnitudes, 13.5 to 16.5, and short cycles, with both narrow and wide maxima.

Six maxima of CZ Orionis were observed by Rosino from August, 1938, to April, 1939. They show a range in magnitude from 12.3 to 16.8, with cycles of 20 to 50 days.

UV Persei was invisible during the whole time it was under observation, from August, 1938, to July, 1939. TZ Persei appears to have the attributes of Z Camelopardalis, with protracted intervals when it remains at a stationary brightness, halfway between maximum and minimum. The limits of variation are between magnitudes 12.5 and 14.7, with short cycles.

Observations for September and October: A total of 8,949 observations — 5,184 in September and 3,765 in October—were contributed by 57 observers, as listed herewith.

	September—1945—October					September—1945—October			
Observer	No. Var.	No. Ests.	No. Var.	No. Ests.	Observer	No. Var.	No. Ests.	No. Var.	No. Ests.
Bell	23	42	..	..	Koons	35	62	20	30
Blunck	64	76	50	63	Ledbetter	7	10	16	40
Boone	16	16	18	18	Luft	..	..	25	701
Bouton	7	8	18	34	Lyons	..	..	2	3
Braitberg	..	..	3	7	Macris	23	41	..	..
Buckstaff	24	71	17	27	Mary	60	109	34	114
Buechner	..	..	19	19	Mount	8	16	11	29
Chandra	57	71	..	..	Nadeau	91	120	117	174
Chrisman	10	10	..	..	O'Byrne	7	18	13	15
Cilley	..	..	23	65	Oheim	92	103	94	134
Cousins	..	..	58	96	Oravec	8	35	20	179
Cragg	95	116	21	43	Parks	17	31	15	30
Dafter	7	17	..	..	Peltier	111	167	141	169
Duffie	31	35	17	19	Petzold	..	..	19	46
Fernald	269	854	300	614	Plakidis	97	664	19	46
Focas	229	1045	..	..	Reeves	2	6	2	5
Ford	16	20	..	..	Renner	66	76	39	44
Garneau	..	..	13	15	Rosebrugh	12	99	15	148
Gemberling	55	104	23	27	Schoenke	8	8	..	..
Guimont	5	5	..	..	Segers	9	24	..	..
Halbach	5	5	..	..	Sill	..	..	65	73
Harris	47	47	27	27	Stahr	..	..	3	4
Hartmann	151	165	142	156	Stowe	22	33	..	..
Holt	108	214	..	..	Topham	..	..	63	64
Howarth	12	12	14	14	Webb	13	26	12	13
Huffer	27	36	..	..	Weber	25	25	45	47
Hukill	3	34	2	21	Williams	..	..	2	5
Kearons	36	42	..	..					
Kelly	10	18	10	17	57	Totals	5184		3765
de Kock	80	348	88	416					

November 15, 1945.

Comet Notes

By G. VAN BIESBROECK

No new comets have been announced this month. PERIODIC COMET KOPFF (1945 *b*), which has now been followed for six months, is still well placed for observation but its decrease in brightness is speeding up. I estimated the brightness as 11.5 on October 23 and 12.5 on November 6 which means that the comet will soon be beyond the power of ordinary telescopes. On the latter date the coma was still 4′ in diameter and still showed a well-condensed central nucleus. The ephemeris given on p. 413 still holds very closely and the object will be well in reach of large telescopes beyond the end of this year.

PERIODIC COMET VÄISÄLÄ (1944 *b*) becomes more difficult. The last record here gives the magnitude as 16 on November 6 but there was no change in the nearly stellar appearance.

Again the region of PERIODIC COMET SCHWASSMANN-WACHMANN 1925 II was explored unsuccessfully on October 30 and November 6. The sky being transparent, stars as faint as magnitude 18 were recorded in the vicinity of the comet but no trace of this elusive object could be found. However, a new attempt on November 15 brought the surprise that the comet was right where expected. It appeared as a round nebulosity some 40″ in diameter, only slightly condensed centrally. The magnitude turns out around 15 which shows that the brightness must have increased more than a hundredfold since November 6. Thus after a long period of low luminosity the comet has once more livened up and it will be interesting to see how it will behave from now on. From past experience the comet may brighten up to 11th or even 10th magnitude but its unexplained fluctuations are so erratic that its behavior cannot be predicted. The comet deserves a careful watch. The following ephemeris by P. Herget follows the comet within a couple of minutes of arc:

	α	δ
1945	h m	° ′
Dec. 3	4 58.8	+32 57
Dec. 19	49.6	32 39
1946		
Jan. 4	42.4	32 13
Jan. 20	37.4	31 43
Feb. 5	35.2	31 15
Feb. 21	4 36.1	+30 51

The positions are referred to the equinox of 1950.

Williams Bay, Wisconsin, November 16. 1945.

Communications and Comments

Under this heading we shall publish from time to time such material as does not properly fall under any of the established headings of this journal. Here, too, may be found, when occasion arises, articles which the editor may not be willing to give sanction to but which, nevertheless, may be provocative of thought along new lines.

The Lack of Impact Craters on the Earth*

Several theories have been advanced to explain the origin of the craters on the moon. The two main theories are the volcanic and the impact theory. There are certain strong arguments on each side and its seems difficult to prove or disprove either one.

One of the main objections to the impact theory has been that the earth shows surprisingly few craters resembling those on the moon. It is claimed that, if the moon were exposed to such a tremendous bombardment of meteorites, the earth certainly should have been too. To me, this no longer holds as an argument against the impact theory.

Let us assume that earth and moon were formed at approximately the same time. The moon, being the smaller one of the two, would have solidified first, while the earth would still have a molten or plastic surface. If, at this time, the earth-moon system were exposed to a bombardment by large meteorites, permanent scars would be left only upon the moon, for it alone had a solid surface.

The polar regions of the moon show many more craters than the equatorial region which is mainly occupied by the relatively smooth "maria" (seas). This fact may be explained by a similar reasoning. The polar regions would probably have cooled first, whereas the equatorial region may have cooled and solidified at a later time when the meteorite shower was on the decline. Moreover, during that period several large meteorites may have broken through the thin crust of the equatorial region, allowing the molten magma to flow out on the surface. This covered up most of the craters that had been formed. These break-throughs happened when the meteorites had diminished considerably in the neighborhood of the earth-moon system, which explains why the "maria" bear but a few signs of meteoric impact.

It is often claimed that the lack of craters on the earth is due to erosional effects. I do not believe erosion and surface disorder could so thoroughly erase numerous large craters on the earth.

I do not mean to imply that the moon had no volcanic activity at all. Some of the smaller lunar craters may have been caused by volcanic action. As a matter of fact, near the crater Copernicus there seems to be a line of small volcanic eruptions much like the ones we have on the earth. They follow a line or weak seam in the crust.

The purpose of this paper is not to condemn the volcanic theory which has many points in its favor. I only wanted to show that the lack of craters on the earth is not a decisive argument against the impact theory. Possibly the lunar craters may have originated from both sources.

STUART J. INGLIS, 2nd Lt., USMCR.

*Transmitted by Professor Gerard Mulders, Occidental College, Los Angeles, California.

Celestial Bombardment of Moon and Earth

Dr. Frederick C. Leonard says in "A Note on the Origin of the Lunar Craters":[1] "Possibly the craters that possess central spires . . . are in general of typical volcanic origin, while those that are devoid of central mountains . . . are, for the most part, either of meteoritic origin or the remains of burst bubbles." This statement seems partially impossible for the following reasons.

The earth has huge volcanoes as exemplified in the Hawaiian Islands, but our largest crater is microscopic in comparison with craters on the moon. Why do we not have craters comparable to those on the moon? The deepest origin of volcanoes is not sufficient to make possible the diameter of lunar craters. To account for a lunar crater the source of the explosion would have to tear a hole with sides at an angle of about 45 degrees. No theory of our volcanoes can account for such craters as the moon possesses.

It is inconceivable that a bubble of gas could have sufficient size or pressure to form a large crater. Gas below the surface of earth or moon would be so greatly compressed as to be liquid or solid. If it were to escape it would do so through small vents and the explosion would occur at or near the surface. Why are there no "bubble scars" on the earth? No law of physics can countenance a large subterranean bubble bursting with sufficient force to form an immense crater.

The only remaining theory is bombardment. The question that immediately arises is: If the large craters on the moon are from bombardment why has not the earth similar craters?

I believe that the earth has similar craters, but they are very much larger than any on the moon. I believe that every inequality on the surface of the earth, above or below the oceans, is of meteoritic origin. I believe that the immense sheets of cobblestone outwash along the Pacific Coast resulted not from slow warping, but from cataclysmic downpours following great upsets in climate and other normal phenomena after the impact of a large meteorite. Many of our mountain chains show parts of the curved crater rims caused by bombardment. The reason for there being no perfect craters of immense size on the earth is that we have suffered so much more heavily than our satellite because of our greater attraction, that our craters have almost disappeared in jumbles. Besides, probably more recent meteorites are smaller than earlier ones.

Mr. Walter Houston in "Notes on Lunar Craters"[2] shows that craters with central spires are not necessarily volcanic. This permanently lays at rest the theory that lunar craters are volcanic.

LITERATURE CITED

[1] Leonard, Frederick C., A note on the origin of the lunar craters, *Contributions of the Soc. for Research on Meteorites*, Vol. 3, 1944, p. 155.

[2] Houston, Walter, Notes on Lunar Craters, *Popular Astronomy*, Vol. 53, October, 1945, p. 421.

CHAPMAN GRANT.

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General Notes

Mr. James W. Fecker, well known in astronomical and other scientific circles because of his important contributions to the mechanical and optical equipment used in these fields, died in the Allegheny Hospital, Pittsburgh, on Sunday, November 11, at the age of 54. An account of his life and work will appear in a later issue of this magazine.

The American Astronomical Society will convene on February 1, 2, 1946, at Columbia University, New York City, for its seventy-fourth meeting. The following tentative program has been announced by the Secretary, Dr. D. B. McLaughin.

FRIDAY, FEBRUARY 1

9:30 A.M. Registration of members begins, Room 313, Pupin Laboratory.
9:30 A.M. Council meeting.
10:30 A.M. Session for papers, Room 301, Pupin Laboratory.
12:15 P.M. Photograph.
12:30 P.M. Luncheon.
2:00 P.M. Session for papers.
6:30 P.M. Society dinner, Men's Faculty Club.

SATURDAY, FEBRUARY 2

10:00 A.M. Session for papers.
12:30 P.M. Luncheon.
2:00 P.M. Session for papers.

Notes from the Yerkes Observatory

DR. GERHARD HERZBERG joined the staff as Associate Professor on September 20. He has for the past two years carried on research work for the Explosive Committee of the Canadian National Research Council at Saskatoon, Canada.

DR. GERARD P. KUIPER returned on November 8, after having been engaged, since July 1, 1943, in research under the Office of Scientific Research and Development at the Radio Research Laboratory at Harvard University. During his absence he made two trips to Europe: On one he was attached to Headquarters of the 8th Air Force Operational Analysis and, on the other, to ALSOS Mission, G-2 of the War Department.

DRS. HENYEY and GREENSTEIN resumed their astronomical duties on November 1. For the past three years they have been engaged in a project for the optical design of various new military instruments under the National Defense Research Committee of the Office of Scientific Research and Development. An optical shop had been established at the Yerkes Observatory for the construction of test models. They are now engaged in the design of optical components for new equipment for the Yerkes and McDonald Observatories. DR. W. A. HILTNER acted as consultant for the optical work carried out at Yerkes under a government contract.

DR. DANIEL M. POPPER, who has been on leave of absence since April, 1943, returned on November 1. He had been engaged in war work at the Radiation Laboratory of the University of California at Berkeley, California, and Oak Ridge, Tennessee. This laboratory was concerned with the separation of the isotopes of uranium by the mass-spectrograph method.

DR. WILLIAM P. BIDELMAN joined the staff as Instructor on October first. For the past two and one-third years he has been engaged in work in terminal ballistics at the Ballistics Research Laboratory, Aberdeen Proving Ground, Maryland.

DR. WASLEY KROGDAHL was appointed Instructor on November 1. Since July, 1943, he has been employed at the Naval Ordnance Laboratory, Washington, D. C., as instructor in physics at the Army Specialized Training Program at Ripon College, Ripon, Wisconsin, and has participated during the last six months in the Navy V-12 and Naval Reserve Officers Training Program at the University of South Carolina.

DR. S. CHANDRASEKHAR, who has carried on a full program of teaching and research at the Yerkes Observatory during the war, was a part time consultant to the Ballistics Research Laboratory at Aberdeen Proving Ground, Maryland. He was recently awarded the C.R.R. National Prize for Mathematics by the Andhra University of India.

OTTO STRUVE.

November 24, 1945.

The Duodecimal Society of America has just announced the conferring of its Annual Award for 1944 on F. Emerson Andrews, Tenafly, N. J., and of the Award for 1945 on George S. Terry, Hingham, Mass.

The Duodecimal Society is engaged in educating the public in counting by twelves, instead of tens, and in the application of the 12-Base in mathematics, weights and measures, and other branches of pure and applied science. Its Annual Awards are conferred on those who have made outstanding contributions to the development of duodecimals, and to the advancement of the purposes of the Society.

Mr. Andrews is Publication Manager for the Russell Sage Foundation. He received his degree in Arts from Franklin and Marshall College, and has written a number of magazine articles on duodecimals, in addition to the book, "New Numbers," which is now in its second edition.

Mr. George S. Terry received his engineering degree in Turbo Electrics from the University of London. He is the author of the "Duodecimal Arithmetic," with its extensive mathematical tables for duodecimals. Among his other works are "The Dozen System," and many papers on duodecimals as applied to the Theory of Numbers.

Library of Congress Exhibition of Discovery of X-Ray

In commemoration of the fiftieth anniversary of the discovery of X-rays, the Library of Congress presented a special exhibition from November 9 through November 18.

Discovered November 8, 1895, by Wilhelm Conrad Roentgen, Professor of Experimental Physics in the University of Wurzburg, the X-ray today is one of the most powerful instruments of science. It is used to probe the very structure of matter, to assist in medicine and surgery, and its applications to industry are manifold.

A copy of the first publication announcing the discovery was included in the exhibition. This was the December, 1895, issue of the "Sitzungs-berichte der physikalischen—medicinischen Gesellschaft zu Wurzburg."

The Cleveland Astronomical Society

Dr. Leo Goldberg of the McMath-Hulbert Observatory of the University of Michigan lectured on "Gaseous Nebulae" at the November meeting of the Cleveland Astronomical Society. He gave the audience an idea of the density and composition of these objects by saying that a tumbler filled with hydrogen into which a thimble full of air and a few dust particles were introduced and then the whole expanded until it was two miles wide and as high as Mt. Everest would be fairly representative of the gaseous nebulae.

The speaker mentioned three types of gaseous nebulae, planetary, diffuse or bright nebulae, and dark nebulae. The planetary nebulae are greenish in color and usually disc shaped. They are of the order of one one hundred-thousandths as dense as our best vacuum on earth, and a million million miles in diameter. They have a bright star in the center which is the hottest thing in the universe. The gas around this star is illuminated by fluorescence caused by ultraviolet light from the high temperature star. Diffuse nebulae are irregular in shape and are also associated with nearby stars. Their illumination may be due to either reflected light from the star or fluorescence, depending on the temperature of the star. The lecture was well illustrated with slides of many of the well-known gaseous nebulae.

The following afternoon, November 10, the Ohio Neighborhood Astronomical Group had the pleasure of hearing Dr. Goldberg speak on "Recent Progress in Solar Physics." His lecture centered on the work done by Dr. Bernard Lyot and the special filters used in his work. This was followed by some very interesting motion pictures of solar prominences taken by Lyot and also by the McMath-Hulbert Observatory staff.

HENRY F. DONNER.

Western Reserve University, Cleveland 6, Ohio.

Book Reviews

The Chemical Formulary, Vol. VII, Edited by Harry Bennett. (The Chemical Publishing Co. of Brooklyn, N. Y. $6.00.)

More than two thousand formulas for mixing and making thousands of products of use and interest to almost anyone are included in Vol. VII of "The Chemical Formulary," published on May 21 by the Chemical Publishing Co. of Brooklyn, N. Y. (Price, $6.00.) An almost universal range of things to make easily and inexpensively at home or in factory, shop or laboratory, are included for the benefit of students, businessmen, housewives, and just plain putterers. These formulas, representing millions of dollars and years or research, have been collected, tested, and edited by Harry Bennett with the assistance of some of the country's ablest chemists from leading industries and universities.

While previous volumes of the Chemical Formulary, issued biennially for the last twelve years, were designed primarily for experienced chemists and technicians, Vol. VII has been edited especially for laymen and will be available through bookstores and by mail order to a wider public. Each of the seven volumes contains different material and can be used separately or in the set.

Vol. VII includes formulas covering everything imaginable in a long index

ranging from adhesives to the various zinc solutions for rust prevention. It covers the latest scientific discoveries in chemistry and industry such as the famous DDT insecticides as well as the newest development in cosmetics, pharmaceuticals, and plastics. With Vol. VII of "The Chemical Formulary" housewives will be able to make anything from cold cream to meat preservatives or roach killer. Farmers will find insecticides, fertilizers, and livestock medicines easy to make at home at low cost. Students, painters, amateur and professional photographers, chemists, small businessmen, and even cooks will find sections specially suited to them.

Mr. Bennett believes "The Chemical Formulary" will be of special assistance to war veterans wishing to start small specialty businesses. Its formulas for cosmetics, pharmaceuticals, polishes, cleaners, lubricants, adhesives, inks, and scores of other products are particularly suitable for such ventures. He stresses that very little capital would be needed as most of the products could be made with home facilities at a low initial cost.

The directions for making the formulas are simple and direct. Most of the ingredients necessary are obtainable at any general or drug store, and for those that are not, the volume contains a long index giving the names and addresses of mail order firms handling specific products.

Nicholas Copernicus, A Tribute of Nations, Edited by Stephen P. Mizwa. (The Kosciuszko Foundation, New York.) This volume of 250 pages is a record of the many and varied ways in which the four-hundredth anniversary of the death of Copernicus was recognized in this country and throughout the world. The numerous commemorative exercises were held at different times. The culminating ceremony took place in Carnegie Hall, New York City, on May 24, 1943, exactly four hundred years, according to the calendar, after the death of Copernicus. At this convocation, presided over by Dr. Harlow Shapley, National Chairman of the Copernican Quadricentennial Committee, a letter from President Franklin D. Roosevelt and one from Wladyslaw Raczkiewicz, the President of the Republic of Poland, were read, addresses in person and by transcription by a number of well-known scientists were heard, musical selections dedicated to Poland were rendered, and "Copernican Citations" were bestowed upon ten persons who were characterized by Dr. Shapley as "modern revolutionaries." These are, named in alphabetical order, John Dewey, Walter E. Disney, Albert Einstein, Henry Ford, Ernest Orlando Lawrence, Thomas Hunt Morgan, Igor I. Sikorsky, Wendell Meredith Stanley, Orville Wright, and James Y. C. Yen.

The contents of the volume are conveniently summarized in the following sentences taken from the Preface by the Editor. "Beginning with the national celebration in New York, with messages of tribute from our leading educators and distinguished scientists, and down through academic and civic celebrations in various communities, planetarium demonstrations, Copernican exhibits, public and private school exercises, addresses and remarks in the United States Congress, public proclamations of governors of states, radio programs, articles in periodic publications and scientific journals, special feature stories and editorial comments in Sunday papers and the daily press—the big and the small, the more and the less significant, all that gives us a cross-section of the tribute of America to the 'Father of Modern Astronomy.' And all that speaks so eloquently for all of America."

The Foreward to the volume is by Dr. Shapley. He entitles it "On Quadri-

centennials" and, with his usual originality, projects himself in thought four centuries into the future and surmises the state of mind of persons living at that time as they review the time in which we are living and, perchance, endeavor to select some one or some event worthy of a quadricentennial celebration at that time. It sets the tone of fine writing which is found throughout the book.

This volume is unique in its contents. It is at once scientific, historical, commemorative, inspirational, and literary. Its conception and execution do great credit to the editor, Dr. Stephen P. Mizwa, Secretary of the Kosciuszko Foundation, and Secretary of the Copernican Quadricentennial National Committee.

C.H.G.

Telecurve Great Circle Map, by Felix Locher and Jon Hall. (Locher-Hall Telecurve Co., Los Angeles 14, Calif.)

The development in the last few years of quick transportation from one point to another, no matter how distant, has naturally led to the use of the shortest routes. When long distances are involved in air travel the great circle route comes prominently into play. In surface travel the great circle course sometimes interposes obstacles which are of no import in air travel. As a result various devices are used for determining shortest distances between points on the earth's surface. One such device is the Locher-Hall Telecurve Great Circle Map. The purpose of this map is stated to be to provide an accurate and quick method of determining, by direct reading, all great circle routes and great circle distances from various centralized starting areas to all parts of the world. The map also provides means for checking the accuracy of world-wide great circle distances previously calculated by other methods in statute miles, nautical miles or kilometers. A 24-hour Time Band gives comparative time and date around the world.

It will be found very useful in seeing the geography of the earth as a whole, instead of in segments as is the case with ordinary maps. C.H.G.